THE EFFECTS OF CONCEPT MAPPING AND COOPERATIVE LEARNING EXPERIENCES ON ACHIEVEMENT, TRANSFER PROBLEM SOLVING ABILITY, AND ATTITUDES TOWARD THE INSTRUCTIONAL EXPERIENCE OF MIDDLE SCHOOL SCIENCE STUDENTS

By

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The purpose of this study was to compare the effects on science achievement, transfer problem solving ability, and attitudes toward the instructional experience for students using concept mapping, cooperative learning, and a combination of concept mapping and cooperative learning in a unit of study. A concept map is a two-dimensional, visual representation of a body of knowledge. Proficiency in concept map construction fosters meaningful learning and positive attitudes toward school and subject. Cooperative learning strategies are structuring techniques for promoting productive student-student interaction in the classroom by creating a situation where each student's success is dependent upon the success of all group members. This study was an investigation of the possibility that a cooperative learning structure can provide the support necessary for middle school science students to experience success with concept mapping.

In this 6-week study, intact classes of middle school science students constructing concept maps in cooperative learning groups were compared with classes constructing concept maps independently and with classes working cooperatively without concept mapping. At the end of one 3-week unit of study in science, and again at the end of a second 3-week unit, selected measures of science achievement and transfer problem solving ability were administered to all students to evaluate the effects of the different classroom structures on these dependent variables. A measure of attitudes toward the instructional experience was administered once when both 3-week units were completed.

Analyses of variance (ANOVAs) conducted for all content units on pretest scores indicated that the treatment groups were generally equivalent on these variables before treatment began. Analyses of covariance (ANCOVAs) indicated no significant overall effects of treatment or gender, but inspection for effects of gender-by-treatment interaction showed that males performed better than females on Genetics measures of science achievement and transfer problem solving ability, and females performed better than males on an Atomic Structure measure of transfer problem solving.

Concept maps were scored using a concept mapping evaluation procedure established for this study. Comparative analysis revealed that

concept maps constructed in cooperative learning groups were less likely to have unconnected concepts or unlabelled propositions. They were less likely to contain errors in content, have concepts out of an acceptable hierarchical order, or lack logical connections. When examined for readability, maps constructed cooperatively were easier to follow than maps constructed individually, suggesting a better overall understanding of unit concepts.

CHAPTER I
INTRODUCTION

Gains in content acquisition, problem solving ability, and attitudes toward science and the instructional experience have been attributed to students using either the metacognitive tool of concept mapping (Novak, Gowin, & Johansen, 1983) or the organizational structure of a cooperative group (Cohen, 1986; Johnson & Johnson, 1989). The many forms of cooperative learning have enjoyed considerable success in producing academic and social growth, but the concept mapping technique has not been as successful. In this study, the possibility that a cooperative learning structure can provide the support necessary for middle school science students to experience success with concept mapping is investigated.

Although the possible benefits of constructing concept maps in cooperative structures have been briefly discussed in the literature (Novak & Gowin, 1984), studies investigating the effects of their combined use have rarely been conducted (Okebukola & Jegede, 1988). The purpose of this study was to investigate the effects on science achievement, transfer problem solving ability, and attitudes toward the instructional experience for students using both concept mapping and cooperative learning simultaneously for a particular unit of study.

The methodology employed for this research study had the following components: (a) three sections each of 7th- and 8th-grade science classes in an overseas American middle school; (b) two experienced science teachers, one per grade level, following a consistent script and procedure whenever possible; (c) selected units of study appropriate for each grade level with related textual materials; and (d) measures of recall or low-level science content knowledge, measures of high-level (application or above) transfer problem solving ability in science, and measures of attitudes toward the instructional experience (one instrument for concept mapping and another for cooperative learning). For each grade level, students in one section constructed concept maps of the material independently to help master unit content, students in a second section covered the material in cooperative groups without concept mapping, and students in a third section constructed concept maps of the material in cooperative learning groups.

The remainder of this introduction includes information about the purpose, hypotheses, and significance of this research study. Introductory information about concept mapping and cooperative learning is also included.

Statement of the Problem

Research findings by Novak and others support the view that proficiency in concept map construction fosters meaningful learning, metacognition, and positive feelings about school and subject (Novak & Gowin, 1984). However, mastery of the concept mapping technique has not always been achieved, and students from all ability levels have encountered difficulties while attempting to become proficient in concept map construction (Lehman, Carter, & Kahle, 1985; Novak et al., 1983).

This was an investigation of the possibility that a cooperative learning structure would provide the support and motivation necessary to ensure that students become proficient in, and therefore derive the maximum benefit from, concept map construction. The fact that concept mapping has been described as a tool that can stimulate academic controversy (Novak & Gowin, 1984) should facilitate this association with cooperative learning procedures, often considered particularly successful when issues discussed have reached the level of controversy (Johnson, Johnson, & Holubec, 1987).

Hypotheses

According to Ausubel (1968), meaningful learning occurs when new information is assimilated and incorporated into an individual's existing cognitive structure. Concept mapping (Novak, 1981) is a learning heuristic that may help students achieve meaningful conceptual growth. It is hypothesized that students constructing concept maps in cooperative learning groups are more likely to achieve mastery in concept map construction and derive the benefits of learning meaningfully than are students constructing concept maps independently or students working in cooperative learning groups without concept mapping. More precise null hypotheses have been formulated on the basis of past experiments.

Hypothesis 1. There is no significant difference among the mean achievement scores on measures of recall or low-level science content knowledge for students constructing concept maps in cooperative learning groups, students constructing concept maps independently, or students working in cooperative learning groups without concept mapping.

Hypothesis 2. There is no significant difference among the mean achievement scores on measures of high-level transfer problem solving ability in science for students constructing concept maps in cooperative learning groups, students constructing concept maps independently, or students working in cooperative learning groups without concept mapping.

Hypothesis 3. There is no significant difference among the mean scores on measures of attitudes toward the learning activity (one attitudinal measure for concept mapping and another for cooperative learning) for students constructing concept maps in cooperative learning groups, students constructing concept maps independently, or students working in cooperative learning groups without concept mapping.

The treatment variables for these hypotheses were (a) the grouping formats of the students for the learning exercise, either individually or cooperatively and (b) the use or nonuse of concept mapping to help integrate new information into existing cognitive structures. The output variables considered were (a) scores on commercial measures of recall or low-level science achievement, (b) scores on commercial or researcher-constructed measures of high-level transfer problem solving ability in science, and (c) results on attitudinal measures of concept mapping or cooperative learning.

It was hypothesized that (a) students constructing concept maps in cooperative groups were more likely to experience success with concept map construction as a result of the academic support, verbal interaction, and elements of positive interdependence provided by the cooperative arrangement, (b) students working cooperatively but without mapping would not benefit from discussions of conceptual relationships stimulated by the visual representation provided by a concept map, and (c) students constructing concept maps independently would not receive peer support or input and thus were less likely to discover conceptual relationships that could contribute to academic achievement.

If it is true that successful construction of a concept map for a particular topic can be interpreted as evidence of higher order meaningful learning, then students successfully using this heuristic should perform better on cognitive measures of that topic than students who are not using the technique successfully or at all. In addition, they should be able to transform this new knowledge and apply it creatively in novel problem solving situations. Finally, if concept mapping can help a student visualize meaningful conceptual growth and metalearning, then success with this heuristic should create positive feelings about the learning experience for a particular topic.

Controls for this study included the following: (a) one science teacher per grade level following a script and specific procedures for monitoring individual and group work, (b) uniform subject matter within each grade level, (c) daily observations by this researcher of in-progress study implementation, (d) the use of pretests to evaluate prior knowledge of the science topic, and (e) a uniform system for evaluating the measures of science content, transfer problem solving ability, and attitudes toward the learning experience at both grade levels.

Significance of the Study

The concept mapping heuristic is derived from Ausubel's (1968) assimilation theory of cognitive learning and focuses on the central role that previously learned concepts play in the acquisition of knowledge and interpretation of events or objects. The extent to which new knowledge relates to these prior concepts or experiences determines whether it will be assimilated meaningfully into cognitive structure.

If concept mapping is a practical application of Ausubel's theory, success with this heuristic could be interpreted as evidence of higher order meaningful learning, that is, learning categorized at the application, synthesis, and evaluation levels of the type described by Bloom (1956). In addition, students who have learned a topic meaningfully, through hierarchical organization of concepts, should be able to transform this new knowledge and apply it creatively in novel situations (Novak & Gowin, 1984).

Students have not always successfully mastered the concept mapping technique. In a study involving middle school science classes, nearly half of the students were not successful in using the concept mapping strategy, and student successes and failures were evident in both the highest and lowest quartiles of ability as indicated by standardized achievement test scores (Novak et al., 1983). Other researchers have also reported mixed findings regarding the claim that concept mapping fosters cognitive growth (Arnaudin, Mintzes, Dunn, & Shafer, 1984; Lehman et al., 1985).

A number of reasons have been suggested to explain the difficulties students and teachers have experienced while involved in concept map construction. The process of learning material meaningfully may be a problem for students and teachers who have spent a large portion of their time in school involved in rote learning. Good concept maps take time and effort to construct, and both students and teachers may prefer to use more familiar learning methods that they have found effective (Novak, 1990). In addition, they may be threatened by the idea of sharing a visual representation of what they know or do not know about a particular subject with other individuals (Arnaudin et al., 1984).

Several references are made in the literature regarding the benefits of constructing concept maps in groups (Ault, 1985; Cohen, 1987; Novak & Gowin, 1984), but rarely have steps been taken to organize these groups cooperatively (Okebukola & Jegede, 1988). Cooperative learning success is attributed to the high levels of student-student interaction that occur as a result of structuring positive interdependence, individual accountability, face-to-face interaction, heterogeneous grouping, and the development of interpersonal skills. This positive student-student interaction in turn provides the peer support and encouragement that could ensure concept mapping success (Cohen, 1986; Johnson et al., 1986; Slavin, 1983).

Cooperative learning has been particularly effective for discussing controversial issues. The two dimensional organization of a concept map provides an ideal format for encouraging low-level controversy as conceptual ideas are visualized, constructed, and criticized. It has been suggested that concept maps are well-suited for sharing and negotiating meanings (Novak & Gowin, 1984).

Positive results of this study could contribute to the solution of practical problems faced by educators and students with respect to concept map instruction, construction, and evaluation. If this study supports the claim that concept mapping proficiency can help a student learn how to learn meaningfully and that concept mapping success can be enhanced through application of the interactive elements of cooperative grouping, it would have important applications.

Concept Mapping

Concept mapping (Novak, 1981) is a strategy designed to help students and educators visualize conceptual meanings from a body of learning material or an individual's cognitive structure. A concept map can be considered a representation of meaning or an ideational framework for a specific domain of knowledge in a particular context (Novak, 1990). The philosophical basis for this heuristic device is that concepts and propositions composed of concepts are the central elements in the structure of knowledge and the construction of meaning (Novak & Gowin, 1984). Based upon Ausubel's (1978) assimilation theory of cognitive learning, concept mapping was originally conceived as a method for investigating a student's ability to solve problems in science. It was also used for organizing interview data in studies investigating changes in conceptual understanding over time (Ault, Novak, & Gowin, 1984).

Ausubel's theory stresses the central role that previously learned concepts play in the acquisition of knowledge and the interpretation of events or objects. These prior concepts form the individual's framework of conceptual interrelationships regarding a particular topic and are a result of his/her idiosyncratic experiences with that topic.

The extent to which new information relates to these prior concepts or experiences determines whether it will be assimilated as rote or meaningful learning (Ausubel, Novak, & Hanesian, 1978). Meaningful learning occurs when a person consciously and explicitly ties new knowledge to relevant concepts or propositions he/she already possesses. In rote learning, new knowledge is arbitrarily introduced into cognitive structure.

Concept mapping involves identifying the concepts in a body of knowledge, organizing them into a hierarchy, and then labeling the relationships between these concepts on connecting lines. Novak and Gowin (1984) suggested that these concepts and the hierarchical relationships between them form a visual approximation of the learner's cognitive structure for that topic. The recommended hierarchical organization of a concept map places the most general, most inclusive concepts at the top with the more specific, less generalized concepts arranged appropriately below (Novak et al., 1983). This conception of psychological organization is based upon Ausubel's claim that meaningful learning occurs when new information is subsumed under previously learned concepts.

Concepts represented on a concept map are generally enclosed in rectangles or ovals with labeled lines connecting these enclosures. The labeled lines represent explicit relationships between the connected concepts (Novak, 1981). The simplest concept map would include two concepts linked by a labeled connecting line forming a unit referred to as a proposition (Novak & Gowin, 1984), as shown in Fig. 1-1.

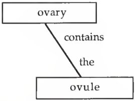


Figure 1-1. A single propositional unit formed by two concepts and a labeled relationship.

Propositions can be organized from general to specific in a hierarchy, or laterally, connecting related concepts from different hierarchical portions of the map. These labeled horizontal propositions or "cross-links" show additional interrelationships and result in a construction that Novak interprets as a two-dimensional representation of a unit of knowledge. As additional concepts are included in the learning material, the concept map grows into an increasingly complex

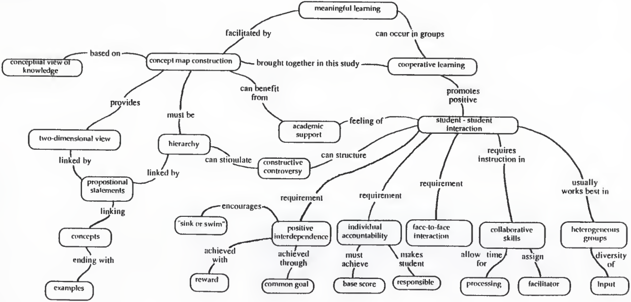


Figure 1-2. A concept map summarizing the main elements of concept mapping and cooperative learning.

structure representing an approximate externalization of the concepts and propositions that make up a topic (Novak & Gowin, 1984) (see Fig. 1-2).

Cooperative Learning

Cooperative learning strategies are structuring techniques for promoting and increasing productive student-student interaction in the classroom. The Learning Together approach of David and Roger Johnson (1991), the Student Team Learning methods developed by Robert Slavin (1983) and others at The Johns Hopkins University, and Elizabeth Cohen's (1986) Heterogeneous Classroom Strategies are among the most established programs of cooperative learning currently in use. Although there are differences among these various approaches, important similarities exist. Cooperative learning activities should include goal interdependence, individual accountability, face-to-face interaction, and group recognition for success. The proponents of these programs advocate the formation and nurturing of social skills but offer different views on the degree to which these skills affect successful group performance. Heterogeneous group composition is usually preferred and a criterion-referenced evaluation system is used.

The basic aim of cooperative learning is to maximize the achievement of each student by creating a situation where student success depends on the learning of other group members as well as the individual's own learning. The format encourages students to work together to succeed regardless of their ethnic background, gender, social status, or ability level. In cooperative arrangements, students work with small groups of peers rather than individually, receiving information and feedback from peers as well as from teachers and curriculum materials. The majority of research comparing student-student interaction patterns indicates that students learn more effectively when they work cooperatively (Johnson, Maruyama, Johnson, Nelson, & Skon, 1981; Slavin, 1983).

Positive goal interdependence is a condition under which students need each other to complete the group's task. A variety of tactics for nurturing positive goal interdependence have been discussed in the literature (Johnson et al., 1986). Usually achieved by the assignment of some mutual, academic group goal, activities are structured so that all members benefit if and only if each individual member masters, to a predetermined degree, the content that the goal requires (Johnson & Johnson, 1987; Slavin, 1983). Students work together to prepare for or complete cooperative tasks ranging from long-term reports or projects to regular, day-to-day class assignments and tests. The product may consist of a single set of answers agreed upon by all group members, accumulation of individual exam improvement points, or be based upon the number of group members reaching a goal successfully. All members of the group are evaluated on the quality of this product or work using preset criteria.

Resource interdependence, role interdependence, and reward interdependence are some of the most commonly used methods for structuring positive goal interdependence. These approaches may be used independently or in conjunction with others. They are an attempt to create peer interaction and support for becoming academically involved (Johnson et al., 1987). The greater the frequency of task-related, student-student interaction, the greater the achievement gains can be (Cohen, 1986).

Resource interdependence can be structured simply by distributing a single copy of an informational packet to a group and requiring all group members to master the contained information. Such a procedure requires that every member participate in some way to successfully incorporate that information into his/her cognitive structure.

Resource interdependence can also be established when each group member is given a different book or set of resource materials to synthesize for all group members. This "jigsaw" format involves distributing part of the information to be mastered by the entire group to each student who must devise techniques to educate the other group members about his/her "piece" of the puzzle (Aronson, Blaney, Stephan, Sikes, & Snapp, 1978). Other forms of this task specialization require dividing a large task into several subtasks and assigning different group members to work on a particular subtask. Cooperative learning structures do not require task specialization, however. Many cooperative learning groups are organized so that all members work on the same content material, although the required degree of content mastery may vary for each individual.

Role interdependence is established when complementary and interconnected roles are assigned to group members. Students can even be trained to perform their roles effectively. The purpose of this procedure is to ensure that all students interact and to compensate for potential status factors that might affect the access of some members to group benefits (Cohen, 1986; Johnson et al., 1987). For example, there can be a summarizer-checker to make sure everyone in the group understands what is being learned, a recorder to write and edit information, an encourager to reinforce contributions, or a facilitator to oversee effective group functioning.

Reward interdependence is a factor in most forms of cooperative learning. All group members are required to attain certain preexisting criteria for the group to achieve some form of recognition. Criteria for success are generally determined by the teacher and include both group and individual performance. Application of this positive group reward when all members have achieved certain individual criteria successfully is an important motivating factor for cooperative learning groups. The rewards can be for the group, for each individual, or some combination of these approaches, and can be concrete such as bonus points or symbolic such as a certificate. The Johns Hopkins models (Slavin, 1983) often use a tournament format with intergroup competition as the basis for promoting a perception of interdependence among group members.

Individual accountability is achieved by requiring each group member to master the content of the assigned material or complete specific assignments successfully for the group to achieve reward status. Each group member has clear objectives for which he/she will be held accountable. A variety of criterion-referenced evaluation materials can be implemented at appropriate times to assess individual performances. Evaluation should be both formative and summative. If formative for evaluating progress, the teacher or group members can determine who has not yet achieved his/her level of mastery, and instructional assistance can be provided before summative evaluation takes place. It is important to frequently stress and assess individual learning so that group members can appropriately support and help each other. In some learning situations, all members may work toward achievement of the same criteria. For others, individual members may be evaluated according to specific criteria. Criteria should be tailored to be challenging and realistic for each individual group member (Johnson et al., 1987).

The aim is to encourage a "sink or swim together" (Johnson et al., 1986) group attitude where students must agree on one theme or set of answers while ensuring that each group member is able to explain the rationale behind these answers. Instead of, or in addition to, rewarding students as individuals, the teacher awards groups of students according to the level of performance they have been able to achieve through their combined efforts. This dependence encourages the perception that students can obtain their goal if and only if the students with whom they are cooperatively linked achieve theirs. They work cooperatively to reach individual goals. Group members assist one another by discussing how to respond to questions on assignments, checking work, or providing feedback or tutorial assistance.

Cooperative learning may be extended throughout an entire class, for example, by awarding bonus points if all groups in a class reach preset criteria of excellence. Groups that are finished with their work are encouraged to help other groups prepare in a cooperative environment (Johnson et al., 1986).

One issue of debate concerns to what degree the formal instruction of collaborative skills is related to successful cooperative learning experiences. Cohen (1986) and Johnson and Johnson (1987) maintain the importance of instructing students in appropriate interpersonal and small group skills such as criticizing ideas without criticizing individuals, and encouraging all group members to participate. They believe that very few students have the collaborative skills needed for effective group functioning, and therefore the skills have to be taught initially. Cohen (1986) and Johnson and Johnson (1987) stress the need for allowing cooperative groups time to analyze and evaluate how well they are using desired social skills. The Student Team Learning approaches of Slavin (1983) and others at The Johns Hopkins University, although recognizing the importance of these cooperative skills, are not as likely to include them in formal instruction.

Cooperative learning situations can involve many degrees of structured academic conflict. Depending upon the content, issues, or instructional materials used, and the group goal assigned, levels of controversy can range from mildly disagreeable to highly argumentative. Research findings (Johnson & Johnson, 1985) indicate that controversy can have a positive influence on both academic and social factors in a cooperative context.

In summary, both academic and social benefits have been attributed to the concept mapping heuristic and the interactive strategy of cooperative learning. However, students have not always successfully completed concept map construction. This study investigated the possibility that the supportive nature of a cooperative learning group would increase the frequency of student success with concept map construction, and that their combined effects would be greater than either used alone.

CHAPTER II
REVIEW OF LITERATURE

This review is a summary of the research on concept mapping and cooperative learning and the theoretical support for these instructional techniques. In the section on concept mapping research I discuss the cognitive and affective gains attributed to mapping proficiency, the support for constructing concept maps in groups, the reluctance of students and teachers to move away from rote learning, and means that have been devised to evaluate meaningful learning.

In the next section I outline Novak's (1984) theoretical support for concept mapping and its natural extension from the theories of Ausubel (1978) and Gowin (1981). Ausubel's cognitive theory of meaningful learning and its components of subsumption, progressive differentiation, and integrative reconciliation are discussed, as well as the influences of Kuhn (1970) and Toulmin (1972) on Novak's development of the concept mapping heuristic. This section is concluded by relating concept mapping to the curricular theory of M. Johnson (1967).

The section on cooperative learning research begins with a discussion of the similarities and differences of the most widely practiced cooperative learning programs. Research substantiating the numerous positive cognitive and affective gains is summarized and the implications of cooperative learning for effective instruction of heterogeneous groups are discussed.

The final section of this research review outlines the theoretical arguments for cooperative learning success. Positive interdependence is singled out as the main element affecting the quality of student-student interaction and the development of interpersonal skills in a heterogeneous environment.

Status of Concept Mapping Research

A variety of qualitative and quantitative research studies have demonstrated the value of concept mapping for producing cognitive and affective gains (Novak, 1990). Concept maps have been successfully constructed by students from kindergarten through college and have been determined to be effective with elementary students for recognition of organizational patterns and review (Stice & Alvarez, 1987), with middle and high school students for success on measures of problem solving in science (Lehman et al., 1985; Novak et al., 1983), and with college students for retaining scientific information (Moreira, 1977). Although both high- and low-ability students have acquired adequate concept mapping skills in short-term studies, mastery of this heuristic has not always been attained (Novak et al., 1983; Stewart, Van Kirk, & Rowell, 1979).

Early concept mapping studies (Bogden, 1977) did not include the procedure of labeling propositional lines, and concept maps were generally constructed by instructors to foster student learning or to select criteria for student evaluation. Researchers analyzing these studies suggested the addition of linking words to promote conceptual development and concluded that the individual constructing the concept map is the person who derives the most benefit from the experience. Later on the importance of stressing the relational, "cross-link" element of a concept map was established (Novak et al., 1983)

Researchers in preliminary qualitative studies focused upon identification and implementation of instructional strategies that would nurture meaningful learning practices like concept mapping and did not attempt to evaluate the effects of concept maps on achievement. Substantial anecdotal data were accumulated from Piagetian-type clinical interviews conducted as part of these studies (Novak et al., 1983).

Concept Maps and Cognitive Growth

University students constructing concept maps for a unit of study made significant gains in science achievement (Okebukola, 1990; Okebukola & Jegede, 1988), in applying knowledge to new situations (Heinze-Fry & Novak, 1990), and in retaining science information (Cliburn, 1987) when compared with students not constructing concept maps. Concept mapping has been related to the learner's cognitive preference orientation (recall, principles, questioning, or application) in which university science students with a principles-oriented learning mode were most successful on measures of meaningful learning (Okebukola & Jegede, 1988). Instructorprepared concept maps have been effective tools for organizing course work in university science courses and for helping students organize information (Ault, 1985; Cliburn, 1986). In addition, concept maps have been useful for documenting and exploring conceptual growth in biology students (Wallace & Mintzes, 1990).

High school science students constructing concept maps have shown a tendency toward a positive effect on measures of meaningful learning when compared with students using text outlining (Lehman et al., 1985; Pankratius & Keith, 1987); and middle school science students using concept mapping as well as Vee diagramming (Gowin, 1981) outperformed students not using these heuristics by wide margins on tests of novel problem solving (Novak et al., 1983). Researchers have shown that the frequency of concept map construction can affect science achievement. High school students completing concept maps both prior to and after a unit of study scored significantly higher on measures of higher order learning than students completing concept maps only after a unit of study (Pankratius, 1990; Pankratius & Keith, 1987).

In a recent study, Mason (1992) investigated the value of concept map construction for helping teachers analyze, prepare, and present subject matter they intended to teach. Over a one semester period, teachers progressed from vague maps with little branching and weak linking words to less linear, more concise constructions that clearly demonstrated the interrelatedness of scientific terms. Inability to create strong propositional relationships indicated inadequacies in the teachers' own subject background knowledge.

Although concept mapping research has addressed instructional, curricular, and evaluative procedures, Novak and Gowin (1984) have advocated its use primarily as a study strategy for students (Ault, 1985; Novak et al., 1983) and as a tool for recording cognitive structure variables in educational research (Ault, Novak, & Gowin, 1984). This latter function has been reflected in construction of the left side of the Interview Vee, a research heuristic designed for inferring a student's cognitive structure. The Interview Vee represents knowledge formation as the result of a series of perceived interactions between concepts, theories, and methodologies.

Researchers involved in a long-term longitudinal study used the Interview Vee to evaluate conceptual changes occurring in students over a ten-year period. Ault, Novak, and Gowin (1988) investigated highly inclusive concepts over time and the influence of prior knowledge on assimilation of new information. They concluded that improved understanding at a later age depends upon early differentiation and integration of concepts and understanding is not the result of specific conceptual connections established in early learning (Ault et al., 1984).

Some researchers have found that concept mapping performance does not correlate with success on standardized achievement tests or traditional measures of course achievement. Students of all ability groups have demonstrated both success and difficulty while attempting to achieve proficiency in the concept mapping strategy. These findings have led to speculation that concept maps require or develop different abilities than those measured by standardized achievement tests (Novak et al., 1983), and that performance on course achievement tests is not necessarily a measure of meaningful learning in science.

A major concern expressed by Novak (1990) with reference to studies of concept mapping and meaningful learning is the difficulty involved in moving teachers and learners away from rote learning. Novak claimed that researchers have underestimated the many changes in curriculum and instruction necessary to successfully incorporate metacognitive tools and meaningful learning. In many studies using concept mapping procedures, teachers reverted to traditional instructional practices a short time after concept map introduction.

Concept map construction is purported to be a measure of meaningful learning (Novak & Gowin, 1984). More research is needed to determine the validity of this claim. If accurate, its use for evaluation would broaden the scope of materials available to educators for that purpose. Researchers have often found it useful to assess concept maps quantitatively, so methods have been developed for assigning values to mapping components and comparisons to ideal maps have been made (Novak et al., 1983). It is impossible, of course, to use concept map performance to compare students using the heuristic for a unit of study with those who have not been instructed in its use.

The results of many studies investigating the use of instructional strategies like concept mapping and its effect upon meaningful learning have demonstrated a pattern that could influence data interpretation for short-term studies (Novak, 1990). Students new to the concept mapping heuristic tend to show a decrease in performance on standardized course exams during the first 2 to 4 weeks before demonstrating increases that often become significant over time (Moreira, 1977). A shift in attitude is also observed over time from negative to positive toward both the concept mapping strategy and the subject.

Concept Maps and Affective Growth

Affective gains have also been attributed to concept map construction. Concept maps may increase a student's awareness of the components of meaningful learning, and success with this learning how to learn strategy could create positive feelings about school learning (Novak, 1981). University biology students constructing concept maps as part of their instruction have demonstrated lower anxiety levels and positive feelings and attitudes toward the instructional experience (Okebukola, 1990).

The interplay between affective and cognitive learning generally leads to more positive feelings toward subject and self (Novak, 1980). These positive feelings could occur as students realize how new information is related to prior knowledge through exposure to the concept map's integrative property (Stice & Alvarez, 1987). Heinze-Fry and Novak (1990) found that most university biology students had positive feelings about their concept mapping experiences. The authors attributed these feelings to the map's potential for demonstrating how an individual learns. Exposure to the process of metalearning may nurture confidence in a student's approach to learning and result in positive effects upon motivation to learn (Novak & Gowin, 1984).

Support for Constructing Concept Maps in Groups

Many researchers have discussed the benefits of constructing concept maps in groups, but most of the grouping arrangements have not been structured in accordance with cooperative guidelines (Johnson & Johnson, 1987; Slavin, 1983); that is, no provision was made for positive interdependence and individual accountability. One study specifically compared concept map construction by university science students working individually with that for students working cooperatively (Okebukola & Jegede, 1988). The results of this study revealed significant gains on measures of meaningful learning for students working in the cooperative mode. Basili and Sanford (1991), working with university chemistry students, also used concept maps in cooperative groups, but the cooperative guidelines were not rigidly enforced. Students in these studies were found to take more responsibility for learning key science concepts.

Other references have been made to using groups for concept map formation but without cooperative components. Partners have been assigned to construct maps jointly (Ault, 1985), and numerous references have been made to the interactive nature of concept mapping (Stice & Alvarez, 1987) and its suitability to group involvement. There are claims that constructing concept maps in groups nurtures discussion, negotiation, and sharing of information and feelings (Miccinati, 1988).

Research findings and theoretical claims support the view that concept maps and subsequent meaningful learning can be successfully developed in cooperative groups. Novak and Gowin (1984) have discussed the potential of concept mapping for sharing or negotiating meanings with other students or the teacher. As a visual, overt representation of a unit of knowledge, the concept map can stimulate dialogue, exchange and sharing of information, compromise, and recognition of missing links and misconceptions.

Gowin (1981) discussed the fact that social interaction can facilitate concept map construction and metalearning or learning how to learn, and that concept maps provide students with insight into the conceptual nature of knowledge. Discussions generated by student-constructed maps can help students monitor their understanding of the learning process (Novak & Gowin, 1984).

Cooperative learning groups could provide a suitable structure for developing the active mental operations that concept maps require and help reconcile new material into existing cognitive structure. The social interaction and motivation of a cooperative group could provide for peer explanations, discussions, and negotiations in an atmosphere of commitment to learning and positive feelings (Johnson & Johnson, 1991).

Ausubel (1968) contended that for meaningful learning to occur, the learner must play an active role in clarifying, categorizing, summarizing, and investigating new information from different angles, and comparing and contrasting new information with prior knowledge. Ausubel also mentioned the importance of encouraging critical appraisal of subject matter. Cooperative learning studies have revealed its potential for nurturing the conditions required for meaningful learning to occur.

Concept mapping researchers have often encountered situations in which students were unable to master the construction of this heuristic (Novak et al., 1983). Novak (1990) suggested that both students and teachers have had problems persevering with the meaningful character of concept mapping. Other researchers have reported mixed findings with regard to its value for promoting cognitive growth (Lehman et al., 1985). Cooperative learning structures could provide the social support and motivation necessary to reduce the occurrence of these problems.

Evaluation of Meaningful Learning

How to successfully evaluate meaningful learning has been a considerable challenge for concept mapping researchers. Novak and others (1981) have designed instruments for measuring a student's ability to transfer knowledge from one setting to a novel problem solving task. It is intended that successful performance on these measures requires student thought at the application, synthesis, or evaluation levels of Bloom (1968), and construction so that rote learning alone is not sufficient for success.

The "Winebottle Test" (Novak et al., 1983) is an example of one measure of higher order thinking skills that has shown some validity. Students are presented with an event, a cork popping out of a warmed, empty wine bottle, and required to explain the event using related concepts, such as expansion and kinetic energy, that they have just studied. Scoring is based upon the number of valid relationships expressed in student responses. Measures of higher order learning have also been constructed by Lehman et al. (1985).

Theoretical Basis for Concept Mapping

Ausubelian Theory

Ausubel's (1968) theory of learning consists of a set of interrelated psychological concepts designed to explain how knowledge is transferred through verbal statements. Three of his major ideas or concepts: subsumption, progressive differentiation, and integrative reconciliation are represented in concept mapping construction (Novak & Gowin, 1984).

Subsumption is the idea that new information is meaningful when it is related to and subsumable under established, more inclusive concepts (Novak, 1977). Ausubel contended that cognitive structure is hierarchically organized with more inclusive concepts and propositions superordinate to less inclusive concepts and propositions. As subsumption occurs for a particular topic, the structure of knowledge becomes progressively more differentiated. The elaboration and refinement of a topic enhance the assimilation of new informational chunks (Novak, 1980).

Progressive differentiation in cognitive structure occurs as additional propositional linkages are formed with related concepts resulting in greater inclusiveness of some topics and greater specificity of others (Novak & Gowin, 1984). As this framework becomes more extensive, the learner can detect meaning in objects or events previously considered unimportant. Novak's definition of learning as a change in the meaning of experience is largely based upon this idea of progressive differentiation (Novak, 1977).

This conceptual reorganization suggests that concept meanings are constantly modified and made more explicit and inclusive (Novak & Gowin, 1984). Meaningful conceptual learning occurs as new propositional links are acquired through progressive differentiation. Constructing additional propositional units on a concept map is viewed as a direct application of this idea.

Integrative reconciliation occurs when two or more concepts in cognitive structure are recognized as relatable in new propositional meanings (Novak & Gowin, 1984). This may involve bringing previously established cognitive links into harmony with new information as similarities and differences in meaning are resolved. Integrative reconciliation of concepts can be expressed on a concept map as valid cross-links (Novak, 1981) are constructed between sets of concepts that might otherwise be viewed as independent. Integrative reconciliation results in at least some further differentiation of related concepts. Its contribution to meaningful learning is the conscious awareness of new relationships between old and new sets of concepts or propositions.

According to Ausubel's (1968) assimilation theory of cognitive learning, meaningful learning occurs when (a) new concepts or concept meanings are linked to existing concepts or propositions the learner already has; (b) new information is subsumed under broader, more inclusive concepts; and (c) acquisition of integrative relationships between concepts is achieved. Novak (1980) would add to these requirements for meaningful learning that (a) the new material be inherently meaningful; (b) the learner has a meaningful learning set, that is, he/she consciously tries to link and incorporate new knowledge with existing, relevant knowledge; and (c) the learner possesses relevant concepts so that subsumption may occur. A meaningful learning set is demonstrated by a student investigating material from different angles, reconciling it with similar or contradictory information, and translating it into his/her own frame of reference.

For new material to be presented effectively by the teacher and acquired meaningfully by the learner, the stability and clarity of prior knowledge must be assured (Ausubel, Novak, & Hanesian, 1978). Meaningful learning occurs when students recognize relationships between concepts as they exist in their minds and as they exist in the environment. As subsumption, progressive differentiation, and integrative reconciliation occur, linking new concepts meaningfully to existing concepts, the structure of knowledge for those concepts can be substantially altered.

Novak and Concept Mapping

Novak regarded educating as the process by which we actively seek to change the meaning of experience (Novak & Gowin, 1984). As concept meanings develop through growth of propositional frameworks, our awareness of objects or events may be altered. Because cognitive structure is the result of an individual's unique interpretation of sensory experiences, the set of propositions a person has describing a concept defines that person's idiosyncratic meaning for that concept (Novak et al., 1983).

The regularity represented by the concept label is given more precise meaning through the addition of propositional statements that include the concept (Novak & Gowin, 1984). Propositions, in turn, gain meaning as the concepts of which they are composed are elaborated. Concepts do not exist in isolation but depend upon their relationships with many others for meaning, and meaningful learning varies with the extent of the learner's relevant cognitive structure (Novak, 1979).

According to Ausubel (1978), the most important factor influencing learning is what the learner already knows; that is, what concepts he/she possesses that are relevant to the topic of instruction. How easily an individual can acquire, integrate, and retain new information into his/her cognitive structure will depend upon this factor.

Novak (1981) has claimed that concept mapping is a practical application of Ausubel's theory. The philosophical basis for concept mapping is that concepts, and propositions composed of concepts, are the central elements in the structure of knowledge and the construction of meaning (Novak & Gowin, 1984). Concept mapping research has been based on the hypothesis that effective meaningful learning occurs as students organize knowledge in hierarchical frameworks, and, consequently, improve their ability to use this knowledge (Novak, 1977).

High success with concept mapping is viewed as evidence of higher order meaningful learning, that is, learning categorized at the application, synthesis, and evaluation levels described by Bloom (1956). Students who have learned a topic meaningfully should be able to transform this new knowledge and apply it creatively in novel situations. Concept mapping contributes to meaningful learning by (a) providing a schematic display of the learner's "cognitive starting place;" (b) increasing the learner's ability to distinguish between general and more specific concepts through its hierarchical requirement; and (c) providing for labeling of lines and the addition of cross-links to strengthen knowledge of relationships between concepts.

Decisions contributing to the arrangement of concepts in a hierarchy appear to be based upon several factors. The degree of inclusiveness or abstraction of a concept, its reference to events or concreteness, or its connections to other concepts all influence hierarchical decisions (Ault et al., 1988). The degree of conceptual abstraction depends on the number of intervening concepts between the concept and examples of events or objects, or the number of connections to other important concepts. The context and focus of the study material are also reflected in hierarchical decisions. No concept is in any absolute sense more or less abstract than another. In one context, a concept may function at a high level of superordinality. When the focus of attention changes, however, that same concept may be subsumed by more inclusive propositions and represent a low level idea (Ault et al., 1988).

Construction of a hierarchical concept map requires reflection on the concepts in a unit of subject matter and subsequent evaluation as most inclusive, less inclusive, and least inclusive. The hierarchy selected suggests a specific differentiation of concepts (Novak & Gowin, 1984).

A concept map is a strategy that can foster learning or understanding of knowledge. Confronted with the visual approximation of what they already know about a particular topic, students can see how knowledge is increased as events or objects are observed through the concepts they already possess. This lesson into the nature or construction of knowledge exposes them to metalearning or learning about learning (Novak & Gowin, 1984).

Evolutionary Views of Knowledge

In addition to the impact of Ausubel's theory on the work of Novak and concept mapping, the writings of Kuhn (1970), Toulmin (1972), and

Gowin (1981) have also been influential. The underlying theme of these epistemological points of view is that knowledge is not absolute but dependent upon the concepts, theories, and methodologies by which individuals view the world.

Information processing systems have been described by Ausubel (1978) with regard to cognitive structure, by Novak with regard to concept mapping (Novak & Gowin, 1984), and by Gowin (1981) with regard to the structure of knowledge. It is hypothesized that as these information processing systems assimilate new information, they are reorganized to accommodate this information. Therefore, these systems are in continuous revision.

Meanings derive from perceived relationships between concepts as they are constructed through the learner's unique sensory experiences (Novak & Gowin, 1984). This human construction of knowledge is subject to the strengths and weaknesses of the ideational frameworks, instrumentation, and emotional fluctuations of human beings (Ault et al., 1988).

Kuhn (1970) has suggested that scientific inquiry is guided, and sometimes constrained, by the conceptual schemes or paradigms scientists construct. He views the history of science as a series of knowledge changes resulting from major shifts in perception occurring as new paradigms replace old paradigms. New factual evidence affects human perspectives and scientists invent new paradigms through which to view reality.

Toulmin (1972) supported this idea of changing perspectives by advocating the evolutionary character of knowledge. Concepts evolve as species do. Human understanding depends upon the conceptual systems and theories that exist in a culture. Because this understanding is based upon the elements of conceptual structure, and concepts evolve over time, theories must also evolve. Toulmin's view of science as built upon evolving conceptual schemes complements a psychology of learning centered on the acquisition and use of concepts.

Gowin and Novak further supported this tentative view of knowledge. Gowin described new knowledge as a "claim" restricted by the context of concepts and methods that produce the claim (Ault et al., 1988). Novak (1977) contended that concepts do not have fixed meanings, but rather meanings derived from the matrix of learned propositions in which they are embedded. The meaning of a concept in any discipline derives from the set of relationships described that use the concept label, and these meanings change over time.

Novak and others (Ault, 1985; Novak & Gowin, 1984) have advocated a variety of curricular uses for concept maps. Novak supported these claims with Ausubel's (1963, 1968, 1978) theory of meaningful verbal learning and Johnson's (1967) model of curriculum. Ausubel addressed the curricular tasks of selecting and organizing content, as well as instructional concerns, within the framework of subsumption, progressive differentiation, and integrative reconciliation. Ausubel made a distinction between curriculum and instruction and Johnson made a similar distinction.

Curricular Theory

Johnson (1967) viewed curriculum as a structured series of intended learning outcomes, involving the selection and organization of the cognitive, affective, and psychomotor objectives of a unit of study. The appropriate examples selected to illustrate the chosen curricular concepts and propositions make up the instructional content of the program.

Concept mapping can be a useful tool for curriculum designers to distinguish between the curricular and instructional aspects of a topic of study. When a concept map includes concrete instructional examples intended to explain the concepts and propositions to be taught, it becomes a guide to instruction as well as to curriculum.

Status of Cooperative Learning Research

Cooperative Learning Approaches

Extensive research has been conducted under the broad heading of cooperative learning. Among the most prominent research movements in this area are the Learning Together program of Roger and David Johnson (1975) at the University of Minnesota, the Student Team Learning program of Robert Slavin (1986) and others at The Johns Hopkins University, and the Heterogeneous Classroom Strategies introduced by Elizabeth Cohen (1986) at Stanford University. These approaches range from the open-ended and student-centered models of Cohen and Johnson and Johnson to the more structured, teacher-centered models of Slavin.

The Johnsons and Cohen advocate familiarizing teachers with the main components of cooperative learning so they may adapt these general guidelines to their unique teaching situations. The teacher is viewed primarily as a classroom manager and consultant promoting effective group functioning as well as individual academic growth. Johnson et al. (1986) and Cohen (1986) believe their methods are particularly suitable for problem solving or conceptual tasks that lend themselves to group discussion, investigation, and controversy. The cooperative development of a group product is the focus of these approaches often involving the pursuit of higher level cognitive objectives. The need for teaching interpersonal skills is viewed as necessary and critical to the success of these methods of cooperative learning.

Models advocated by The Johns Hopkins University researchers (Slavin, 1983) have been very successful for teaching skills and meeting objectives with one set of answers. These models generally follow a step-by-step procedure and appear very appropriate for work in math and other subjects that emphasize individual practice of specifically sequenced skills. Slavin (1983) used intergroup competition as the vehicle for promoting a perception of interdependence among group members. For these models, direct teacher instruction is followed by practice in cooperative groups. Long-term curricular packages have been developed specifically for elementary math and language arts that use cooperative learning as the predominant instructional strategy.

Although researchers disagree about which cooperative learning processes work best and for what purposes, the bulk of the research conducted thus far indicates that student-student interaction conducted in a cooperative setting can produce both cognitive and affective development. The peer support and acceptance that a cooperative arrangement nurtures affect the quality of peer interactions taking place which, in turn, affect social and cognitive development (Johnson & Johnson, 1989). These results have been found for students of all age levels, attending inner city, suburban, or rural schools, and involved in any one of a wide range of subject areas and tasks (including science and science-related activities). Students working in cooperative learning groups have been successful on tasks involving concept attainment, verbal problem solving, categorization, spatial problem solving, retention, and memory (Johnson & Johnson, 1991).

Researchers in several hundred studies have compared the impact of competitive, individualistic, and cooperative learning structures on cognitive and affective outcomes. The majority of this research indicates that students learn more effectively in a cooperative format (Johnson & Johnson, 1991). A meta-analysis of 122 research studies comparing learning structures indicated that students achieve more in cooperative interactions than in competitive or individualistic learning structures. These results were found for several subject areas and involved age groups from elementary school children to adults (Johnson et al., 1981).

Cooperative Learning and Cognitive Growth

Cognitive gains by students working in cooperative groups have also been documented in other cooperative learning summaries (Johnson, Johnson, & Maruyama, 1983; Slavin, 1983). These results suggest that cooperative learning methods are feasible in many classroom situations and likely to have positive effects on achievement and other outcome variables. Slavin (1983) conducted 41 studies of cooperative learning groups in regular classrooms and observed significantly greater learning by experimental groups in 26 of these studies. The results of only one study showed significantly greater learning in a control group.

Another review of Student Team Learning methods indicated significant achievement gains by students in 29 of 35 experimental groups. In most cases, control groups were composed of subjects working in traditionally taught classes studying the same sets of objectives as the experimental groups. None of the studies on Student Team Learning methods resulted in findings favoring control groups (Slavin, 1983).

Researchers have found that students working cooperatively learn course material faster, retain it longer, and make significant gains in achievement for conceptual and problem solving tasks (Johnson et al., 1981; Skon, Johnson, & Johnson, 1981). When structured effectively, students involved in cooperative small group activities develop higher quality strategies for understanding and responding to tasks (Johnson, Skon, & Johnson, 1980), make greater use of higher level reasoning (Johnson, et al., 1987), and develop critical reasoning power more rapidly than students not working cooperatively (Johnson & Johnson, 1991). The results of some studies have indicated that academic gains are most significant for minority and low-achieving students (Slavin, 1983) and that black and Hispanic students show the greatest gains in achievement from cooperative learning arrangements (Good & Brophy, 1987).

Cooperative Learning and Affective or Collaborative Growth

Positive effects on outcomes other than achievement have also been impressive. Researchers have concluded that student attitudes toward school, teachers, subjects (including science), and instructional activities are more positive as a result of participating in cooperative formats than under competitive or individualized conditions. Greater intrinsic motivation to learn in cooperative settings has been demonstrated in studies by both Slavin (1983) and Johnson and Johnson (1985), as well as positive effects on classroom climate, attendance, and internal locus of control (Johnson & Johnson, 1989; Slavin, 1983). In addition, students working cooperatively may exhibit a greater perceived likelihood of success and view success as more important (Johnson & Johnson, 1991). Cooperative learning structures have also reduced math and science anxiety for girls expressing such concerns.

Compared to competitive and individualized conditions, students working cooperatively engage in more positive interpersonal relationships with peers. This is characterized by increased frequency of acts of assistance, encouragement, and friendliness and holds true regardless of differences in student ability level, sex, handicapping conditions, ethnic membership, or social class (Johnson et al., 1983; Johnson & Johnson, 1991; Slavin, 1983). Students cooperatively involved in problem solving situations seek new information from each other more than students working competitively and make optimal use of information provided by other students. These greater perceptions of peer academic support are attributed to the atmosphere that the obligations of positive interdependence nurture (Johnson & Johnson, 1991; Johnson et al., 1980).

Cooperativeness has been positively related to self-esteem in students from elementary, middle, junior high, and high school and in urban, rural, and suburban settings (Johnson & Johnson, 1991). Academic self-confidence is promoted as a result of perceived acceptance of verbal contributions, and low-achieving students benefit from immediate peer tutoring. In addition, a sense of accomplishment can result from suggesting solutions to problems (Johnson et al., 1981; Johnson & Johnson, 1991; Slavin, 1983).

Some researchers have investigated the importance of developing interpersonal social skills for cooperative group success. Methods like Learning Together that set a high priority on developing collaborative skills have proven less likely to produce significant advantages in achievement over traditional formats (Slavin, 1983). Johnson and Johnson maintained, however, that as the quality of interaction in small groups is enhanced through training, students spend more time on tasks and engage in more detailed explanations. This results in greater retention of information and critical thinking experiences (Johnson & Johnson, 1989). Students develop better social skills and engage in them more frequently when the teacher monitors this behavior for the accumulation of group bonus points.

Heterogeneous Grouping

Cooperative learning experiences in heterogeneous classrooms tend to promote greater cognitive and affective perspective taking than do competitive or individualistic conditions with group members being viewed as enriching resources with different perspectives. The frequent exchange of information that can occur in a cooperative group is assumed to promote more differentiated, dynamic, and realistic views of other students (Johnson & Johnson, 1991).

Students working cooperatively demonstrate greater acceptance of differences among peers, and researchers focusing on heterogeneous classes have found the most positive acceptance levels in mainstreamed situations where learning handicapped students worked cooperatively with nonhandicapped classmates (Johnson et al., 1983; Johnson & Johnson, 1991; Slavin, 1983). In addition, researchers have indicated improved race relations among students working cooperatively in integrated classrooms and have suggested that the use of cooperative learning in heterogeneous classrooms can reduce the need for separate special education classes and ability tracking (Slavin, 1983).

In a study comparing intergroup competition to intergroup cooperation (Johnson & Johnson, 1985), the latter condition promoted more inclusion of minority students in the learning process, more cross-ethnic relationships, and more differentiated views of students with factors other than ability recognized as valuable. This greater inclusion of minority students resulted in less difference between the achievement of minority and majority students when intergroup cooperation was used. These effects are attributed to the procedure of linking minority students positively with majority students in the classroom.

Studies have also been conducted to investigate the effects on student achievement of group composition and the interaction patterns of students during group meetings (Webb, 1982). These studies involved groups of four students whose interactions were tape recorded for later analysis. Results of these studies suggest that giving explanations to other group members correlates positively with achievement and that explaining material to others can be an effective learning experience for the explainer as well as the person receiving the explanation. In addition, students who ask pertinent questions and succeed in getting their questions answered demonstrate higher levels of performance on achievement measures than their peers who did not ask questions.

Cohen (1986) has found that gains in achievement are directly related to the frequency of productive student-student interaction, and that status factors can affect this frequency. Expectations for academic competence can become linked to social position resulting in domination of interactive patterns by popular students. To assure that all students benefit from group interaction, Cohen advocated training programs and role assignments to facilitate participation of all members.

Gender Differences

Heterogeneous group composition is considered a fundamental component of cooperative learning success (Cohen, 1986; Johnson & Johnson, 1991; Slavin, 1983). This heterogeneity contributes to positive student-student interaction by providing a wide range of experiential input and points of view. When heterogeneity of cooperative learning groups is discussed in the literature, integration by gender, race, and academic achievement are all required. Of these components, the element of gender has usually received less attention than ethnicity or achievement (Conwell, Griffin, & Algozzine, 1993). Perhaps this is partly because of the heavy emphasis that has been placed upon cooperative learning as a method for improving race relations in schools (Slavin, 1983).

Becker (1989) conducted a reanalysis of accumulated data on gender differences and science achievement and concluded that gender differences were a weaker predictor of scientific outcomes than ethnicity, race, or cognitive ability. Becker concluded that subject matter content was the only area in which significant differences between males and females were found, with males showing advantages over females in studies of biology, general science, and physics.

In a recent cooperative learning study involving students in intermediate-grade level science classrooms (Conwell et al., 1993), significant gender effects were observed for students working cooperatively. These groups were heterogeneous for gender and race and participated in an inquiry-based science activity where manipulatives were used to test ideas. In this study, males were found to be significantly more influential within the group than females with regard to decision making. This was manifest both by more verbal initiation of proposed solutions to problems and by more active testing of hypotheses with manipulatives. Females, on the other hand, when acting as facilitators, were significantly better than males at encouraging all members to particiipate in activities.

Webb (1984) investigated the effects of gender group composition on achievement and patterns of interaction. In this study, students were heterogeneously placed into cooperative learning groups with four members. Groups could be composed of (a) equal numbers of males and females, (b) three males and one female (majority-male groups) , and (c) three females and one male (majority-female groups). The results of this study indicated that achievement and interaction patterns were nearly identical for both boys and girls in groups composed of equal numbers of males and females. In majority-male groups and majority-female groups, however, males showed higher achievement than females. In majority female groups, females focused much of their attention on the male member of the group who was often apathetic to their requests. In the majority-male groups, males focused their attention on the other males and tended to ignore the female member.

Cooperative Learning and High-Achievers

Although cooperative learning experiences appear to be viewed positively by socially-oriented students and those who receive help from peers, questions arise about their value for students who prefer to learn alone and academic student leaders who assume much of the responsibility for tutoring in cooperative learning formats (Good & Brophy, 1987). Johnson and Johnson (1991) maintained that high achievers working in heterogeneous cooperative groups perform as well as bright students working competitively or individually on tests of achievement. High achievers in cooperative groups have scored higher on tests of retention, used higher level reasoning strategies more frequently, and engaged in more in-depth critical analyses and elaborative explanations (Johnson et al., 1986). Their development of collaborative skills and friendships while engaging in cooperation is believed to have a positive influence on their self-esteem and attitudes toward subject matter and the instructional experience.

Structured Controversy

Involved participation in cooperative learning groups inevitably produces conflicts of ideas and opinions (Johnson et al., 1986). These academic disagreements can range from mild negotiation to heated argumentation. Recent research has explored the use of cooperative groups for structuring discussions of controversial issues (Johnson & Johnson, 1985). Findings from these studies suggest that controversy can have a positive influence on learning within a cooperative context.

Cooperative controversies utilize the elements of positive goal and resource interdependence to minimize negative peer conflict. Peer academic support is maintained while controversies are discussed without displays of negative attitudes among participants. In a structured controversy, the teacher assigns students to groups of four that are heterogeneous with regard to achievement, gender, and ethnicity. Each group is then separated into two pairs. Each pair is presented with materials supporting either a pro or con position of a particular issue, asked to learn the supporting arguments, and then to present their view to the opposing pair (Johnson & Johnson, 1985). The format for these presentations provides an opportunity for discussion of differences and verbalization of both positive and negative criticism. After this occurs, student pairs are instructed to reverse their perspectives and present the opposing position as sincerely and forcefully as they can.

Following this procedure, students drop their advocacy, compare the strengths and weaknesses of the two positions, and attempt to reach a group consensus on the issue. This consensus is exemplified in a quality group report supporting their position (ideally a synthesis of the two points of view) on which all group members will be evaluated (Johnson et al., 1987). Individual accountability takes the form of a test on content covered in both positions, an oral presentation with all group members contributing, or both. Groups whose members all score above a preset criterion of excellence receive some form of recognition.

The collaborative skills encouraged in such cooperatively structured controversies stress criticism of ideas but not individuals as intellectual positions are advocated, criticized, and evaluated. The intention of such a structured format is that all ideas are brought forth and then synthesized into a consensual decision.

Research findings support numerous academic and social benefits derived from participation in such structured controversies. Studies have compared structured controversies to competitive debates, individualized instruction, and groups discouraged from disagreeing. In these cases, students participating in structured controversies have demonstrated more verbal rehearsal and exchange of the assigned information, greater mastery and retention of subject matter, higher quality problem solving ability, and easier transition to higher levels of cognitive and moral reasoning (Johnson & Johnson, 1985).

The process of arguing and then coming to a joint conclusion creates positive attitudes toward science and school. These attitudes are characterized by greater motivation to learn, higher epistemic curiosity, an increased desire to search for more information, and more enjoyment of the instructional material and subject matter (Johnson & Johnson, 1985, 1989). Participants in structured controversies are more positive about taking part in discussions, give more peer academic support, enjoy higher self-esteem and are more likely to reevaluate their own positions and compromise or change attitudes (Johnson & Johnson, 1985, 1989).

Results of structured controversies have been particularly positive for academically handicapped students (Johnson & Johnson, 1985). Although there is considerably more interaction among all students in general, the most significant differences in interaction are between nonhandicapped and academically handicapped students. Presumably to prepare all group members for measures of individual accountability, nonhandicapped students choose discussions with handicapped peers over nonhandicappped group mates. This is interpreted as a more accepting and supportive relationship among handicapped and nonhandicapped peers (Johnson & Johnson, 1985, 1989). Although there is typically considerable rejection of handicapped students by their nonhandicapped peers (Johnson et al., 1983), structured academic controversies tend to promote strong cross-handicap interpersonal attraction even when there are considerable differences in ability to engage in intellectual discussion.

Summary

The overwhelmingly positive research findings for cooperative learning experiences are open to some speculation. In many cases, experimental groups were experiencing cooperative learning for the first time and for a limited number of weeks, raising questions about novelty and the long-term effects of cooperative learning. Teachers have commented on the considerable initial preparation required to adapt traditional lessons into cooperative formats and the time required to teach and maintain the procedures and interpersonal skills required for productive group work (Tyrrell, 1990).

Successful performance on measures of achievement for students working cooperatively appears to be primarily related to the use of specific group rewards based upon each member's individual performance. Although Student Team Learning methods using intergroup competition as the incentive for group rewards have demonstrated consistently positive effects on student achievement, so have other reward systems that are not competitive. What is required is that provisions are made for specific group rewards based on the cumulative performance of individual group members. Good results have been obtained by giving team certificates for groups meeting preset standards regardless of the performance of other teams and by using task specialization to motivate students to encourage their group members (Good & Brophy, 1987). Research has also shown that the magnitude of the group reward is not as important to students as the motivating effect of individual success for team success.

The effects of cooperative learning on achievement, therefore, appear to be primarily motivational. However, the motivation to successfully compete against other teams is not as important as the desire to achieve individual goals and thus ensure team success.

Theoretical Basis for Cooperative Learning

The nature of student-student interaction is at the heart of cooperative learning theory. How instructional goals are structured controls the type of student-student interaction that will occur. This in turn controls the instructional outcome. Learning goals can be structured competitively, individually, or cooperatively, and these structures can affect how students feel about school, teachers, each other, and themselves (Johnson & Johnson, 1989).

Positive Interdependence

A student's performance in a cooperative group has consequences for other team members. Positive reward interdependence is fostered in cooperative learning techniques by creating a condition where one student's success helps others to be successful (Slavin, 1980). Students in cooperative settings are viewed as capable of learning on their own and from one another. It is assumed that children are aware of their strengths and weaknesses and can serve as strong motivators for moving peers toward task completion (Slavin, 1983).

Cooperative learning groups are designed to promote an environment of support nurtured by the element of positive interdependence. Two responsibilities are delegated to students. First, they must learn the material themselves, and second, they must help their teammates master it. Positive interdependence leads to a promotive interaction pattern among students where individuals encourage and support each other's efforts to achieve. Determining individual levels of mastery is necessary and must be a frequent occurrence so that students can continue to provide support and assistance to each other when it is required.

Student-Student Interaction

The quality of the peer interaction and relationships that cooperation nurtures can have a widespread and powerful impact. Peers can serve as models or provide opportunities for reinforcing prosocial behavior. Promotive interaction is characterized by personal and academic acceptance and support, high intrinsic achievement motivation, and high emotional involvement in learning (Slavin, 1983).

The verbal interchange that occurs as students work to fulfill their responsibilities nurtures the sharing and caring aspects of cooperative learning. The same type of peer support that characterizes sport teams motivates students to participate in more oral discussion as they summarize, listen, and evaluate each other to determine levels of mastery (Johnson & Johnson, 1991). Students deepen their understanding of material and gain a sense of accomplishment as they explain ideas to others or suggest solutions for problems. The format maximizes explaining and minimizes listening. Metacognitive growth can be achieved as students verbalize and learn how they learn and listen to strategies that others have used (Tyrrell, 1990). Exposure to multiple perspectives inherent in group work fosters analysis, synthesis, and evaluation.

Cooperative learning is based on the assumption of the social construction of knowledge and the idea that cognitive functions appear first on the social level and then on the individual level. It is argued that cooperation should increase group cohesiveness both because it increases contact among group members and because people tend to like those who help them achieve their own rewards (Johnson & Johnson, 1991).

Retention of information is closely linked with the formation of concepts and schemata that can be formed and modified via communication with others in group discussions. Cognitive rehearsal strategies can increase retention and these readily take place in small groups.

Heterogeneity

The idea that cooperative learning can constructively deal with student heterogeneity in classrooms focuses on the quality of interactions among ethnic groups. Cooperative relationships among heterogeneous groups tend to produce acceptance of differences and encourage exploration of different perspectives. Heterogeneous groups are considered the most powerful for problem solving situations due to the variety of perspectives resulting from a mix of backgrounds, skills and points of view. Theoretically, cooperative learning would require students to get to know and work with classmates of different ethnic, racial and cultural backgrounds as students are socially integrated in a way that facilitates their learning and interest and brings an awareness of similarities and differences (Johnson & Johnson, 1991; Slavin, 1983).

Teacher selection of group composition is required to ensure heterogeneity of gender, ethnicity, and achievement. Group size is dependent upon the amount of experience students have at working collaboratively and by the number of students needed to stimulate each other's thinking while ensuring participation of all (Johnson & Johnson, 1991).

Membership on a cooperative learning team provides the initial impetus for students to work. As they begin to achieve academic success, they become more confident in their roles and begin to work harder. All students find their exertion important and realize that they can contribute to the team. Students do not need to depend entirely on the teacher and are encouraged to draw upon their own creativity and that of their peers (Tyrrell, 1990).

Summary

Cooperative learning experiences promote development of basic interpersonal skills (Johnson & Johnson, 1991). These cooperative skills are needed to maintain career, family, and community relationships basic to every individual, as well as provide problem solving and inquiry experiences that may be necessary in the work place. Teaching students interpersonal and small group skills helps bring each member's learning to the maximum by maintaining good working relationships.

CHAPTER III
PROCEDURES AND METHODS OF ANALYSIS

In this 6-week study, intact classes of middle school science students constructing concept maps in cooperative learning groups were compared with classes constructing concept maps independently and with classes working cooperatively without concept mapping. At the end of one 3-week unit of study in science, and again at the end of a second 3-week unit, measures of low-level science content knowledge and measures of high-level transfer problem solving ability in science were administered to all students to evaluate the effects of the different classroom structures on these dependent variables. Two measures of attitudes toward the instructional experience (one for concept mapping and another for cooperative learning) were administered at the end of the second three-week unit (See Table 3-1). A more detailed diagrammatic flow chart for each 3-week unit is presented in Appendix A.

Setting and Research Participants

The setting for this study was an overseas American middle school. Approximately 60% of the school population were United States citizens and the remaining 40% represented more than 40 other

Table 3-1

Study Design for Two Consecutive 3-Week Units in Science

Group	Unit 1		Unit 2		
	Science Content and Transfer Problem Solving Pretests	Science Content and Transfer Problem Solving Posttests	Science Content and Transfer Problem Solving Pretests	Science Content and Transfer Problem Solving Posttests	Measure of Attitudes Toward Instructional Experiences
Teacher (Grade 7)					
Classroom 1 - CM independently	x	x	x	x	x
Classroom 2 - CL without CM	x	x	x	x	x
Classroom 3 - CM with CL	x	x	x	x	x
Teacher (Grade 8)					
Classroom 1 - CM independently	x	x	x	x	x
Classroom 2 - CL without CM	x	x	x	x	x
Classroom 3 - CM with CL	x	x	x	x	x

Note. CM = concept mapping; CL = cooperative learning nationalities. Of this remaining 40%, more than half had attended schools providing an American curriculum for at least 1 year. Approximately 10% of the school population were non-native English speaking students who demonstrated varying degrees of English proficiency.

Participants in this study were 132 seventh and eighth graders. A grade-level by gender distribution of this sample is shown in Table 3-2. The 66 seventh graders and 66 eighth graders were divided into three sections per grade level with from 20 to 23 students per section. This assignment to academic sections was traditionally accomplished by teacher selection in an effort to maintain heterogeneity with respect to ability, gender, and ethnicity and was not by random selection.

Research Design

Classes of two teachers (one seventh and one eighth grade teacher) were used in this study. Each teacher had 15 or more years of previous science teaching experience and had been consistently judged above average on indicators of teaching ability. These teachers, who already were familiar with the basic elements of cooperative learning and concept mapping, were trained and instructed by the researcher prior to the study and monitored for fidelity throughout implementation. The students in three sections of these seventh and eighth grade science teachers' classes participated in this study. The three sections per grade

Table 3-2

Sample Distribution by Grade Level, Gender, and Treatment Group

Grade	CM only		CL only		CM with CL	
	male	female	male	female	male	female
Seventh	10	12	9	13	10	12
Eighth	13	8	12	10	11	12

Note. CM is concept mapping and CL is cooperative learning

level were all taught by the same teacher and assigned to treatments using a random number table.

As a result of the treatment assignments, only two groups were contrasted on each of the attitudinal measures. The measure dealing with attitudes toward cooperative learning was administered to the group working cooperatively without mapping and to the group working cooperatively with mapping. The measure dealing with attitudes toward concept mapping was administered to the group mapping independently and to the group mapping cooperatively (See Table 3-3).

Table 3-3

Administration of Attitudinal Measures

Treatment	Concept Mapping Measure	Cooperative Learning Measure
Mapping Only	X	
Cooperative Only		X
Mapping and Coop	X	X

Description of Treatments

The cooperative learning groups in this study were expected to focus on the completion of a group product and the achievement of high level cognitive objectives. Students were encouraged to discuss issues critically and practice positive interpersonal skills (See Appendix B). Because these components are consistent with the Learning Together philosophy of David and Roger Johnson, most cooperative grouping procedures followed guidelines developed by Johnson et al., (1987). These procedures included establishment of positive interdependence and individual accountability, as well as provision for monitoring and group processing.

The procedures for constructing heterogeneous groups and establishing base scores followed guidelines developed by Slavin (1983). One student facilitator was also designated for each cooperative learning group in accordance with guidelines developed by Cohen (1986). These facilitators were not intended to be strong leaders who might inhibit creative student-student interchange. Their function was to help provide group efficiency and prevent status factors from limiting group access for any student. In this study, they were instructed by the teacher to encourage participation by all members, to keep the group on task, and to intervene if students with high academic or social standing were dominating group discussions or decisions. To assure each group's acceptance of this student facilitator, Cohen suggested that the teacher explain the specific duties of this person to all students and make it clear that the facilitator was carrying out a specifically assigned task. The researcher, with support from another staff member familiar with the facilitator's role, trained these students using guidelines suggested by Cohen. This training took the form of two, 1/2 hour, role-playing sessions.

Organization of all concept mapping procedures followed guidelines developed by Novak and Gowin (1984) and stressed the element of cross-links in construction. Cross-links are horizontal propositions connecting sub-domains of conceptual structure and are regarded as examples of higher order learning (Heinze-Fry & Novak, 1990; Novak et al., 1983).

Science units were selected in an effort to introduce content that students had not likely encountered in their previous schooling experiences. Introductory teacher lectures provided basic information intended to bring students to approximately the same entry level. This is in accordance with Ausubel's (1968) theory of providing a conceptual starting place for students to meaningfully link new information. Ausubel contended that this new information could then be transformed and applied to novel situations.

Instrumentation

The overall hypothesis of this study focused on three broad outcome variables: (a) recall or low-level science content knowledge; (b) high-level transfer problem solving ability in science, and (c) attitudes toward the learning activity. These three constructs were operationally defined with a variety of standardized and researcher-developed instruments. Although the constructs for outcome variables were the same for both seventh and eighth grades, specific instruments for measuring these outcomes differed to match the science curricula taught at these grade levels. Tables 3-4 and 3-5 identify the multiple instruments used to operationalize these constructs for seventh and eighth grades respectively.

Commercial Measures of Science Content and Problem Solving

Measures of science content were administered both before, as pretests, and after each 3-week unit of study at each grade level. These commercially-produced content measures were part of the evaluation

Table 3-4

Commercial and Researcher-Constructed Measures Used to Evaluate the Constructs for this Study (Seventh Grade)

Hypothesis	Construct (dependent variable)	Instrument	Maximum Possible Score	Source
1	Recall Science Content Knowledge	Genetics Chapter Subtest (low-level items)	41	Commercial Publisher
1		Animal Behavior Chapter Subtest (low-level items)	54	Commercial Publisher
2	Transfer Problem Solving Ability in Science	Genetics Chapter Subtest (high-level items)	30	Commercial Publisher
2		Nuclear Reactor	15	Researcher-Constructed
2		Animal Behavior Chapter Subtest (high-level items)	6	Commercial Publisher
2		Animal Behavior Video	40	Researcher-Constructed
3	Attitudes Toward Instructional Experience	Attitudes Toward Concept Mapping	14 items (Likert Scale)	Researcher-Constructed
3		Attitudes Toward Cooperative Learning	16 items (Likert Scale)	Researcher-Constructed

Table 3-5

Commercial and Researcher-Constructed Measures Used to Evaluate the Constructs for this Study (Eighth Grade)

Hypothesis	Construct (dependent variable)	Instrument	Maximum Possible Score	Source
1	Recall Science Content Knowledge	Solids, Liquids, and Gases Chapter Subtest (low-level items)	38	Commercial Publisher
1		Atomic Structure Chapter Subtest (low-level items)	17	Commercial Publisher
2	Transfer Problem Solving Ability in Science	Solids, Liquids, and Gases Chapter Subtest (high-level items)	6	Commercial Publisher
2		Winebottle	5	Researcher-Constructed (Novak & staff, 1981)
2		Bell Jar	8	Researcher-Constructed
2		Atomic Structure Chapter Subtest (high-level items)	30	Commercial Publisher
3	Attitudes Toward Instructional Experience	Attitudes Toward Concept Mapping	14 items (Likert Scale)	Researcher-Constructed
3		Attitudes Toward Cooperative Learning	16 items (Likert Scale)	Researcher-Constructed

program accompanying the student text and were, therefore, regarded as the most appropriate instruments for operationally defining the variables under consideration.

The two content tests administered to seventh graders were from chapters on Genetics and Animal Behavior from Merrill's *Focus on Life Science* (Heimler & Daniel, 1987). The two eighth grade tests were from chapters on Atomic Structure and Solids, Liquids, and Gases from Merrill's *Focus on Physical Science* (Heimler & Price, 1989). These tests were divided into sections designed to measure different levels of learning (See Tables 3-6 and 3-7). Introductory test sections included multiple choice or fill-in-the-blank items aimed at evaluating recognition or recall of concepts and ideas. Middle sections included items designated as measuring the understanding of relationships among facts and concepts. The last section entitled Using Concepts included items designed to measure a student's ability to apply concepts introduced in the chapter to new situations and was regarded by the publisher as the most challenging section of the test.

Prior to test administration, each chapter test was examined by two members of the teacher support group to evaluate the publisher's claims regarding test sections and corresponding measurement of levels of learning (recall vs. problem solving). Although they generally agreed with the publisher's recommendations, questions were raised about the criteria used to determine item difficulty. Members of the teacher

Table 3-6

Specifications for Merrill Chapter Tests: Animal Behavior and Genetics (Grade 7)

Section	Title	Item Types	Learning Level (Merrill)	Number of Test Items	
				Animal Behavior	Genetics
A	Understanding Concepts	Multiple Choice	Recognition/Recall	15	14
B	Interpreting Concepts	Term Selection; True/False	Discovering Relationships	16	18
C	Using Concepts	Short Answer; Sequencing Information	Application	14	17
D	Completing Concepts	Fill in Blanks	Recognition/Recall	15	15

Table 3-7

Specifications for Merrill Chapter Tests: Solids,Liquids, and Gases and Atomic Structure (Grade 8)

Section	Title	Item Types	Learning Level (Merrill)	Number of Test Items	
				Solids, Liquids, & Gases	Atomic Structure
I	Testing Concepts	Multiple Choice	Recognition/Recall	28	17
II	Understanding Concepts	Short Answer	Discovering Relationships; Interpreting Information Compare and Contrast	10	30
III	Applying Concepts	Essay	Application	6	NA

Note: Items from Section III of the Atomic Structure chapter test measured content not discussed by the 8th grade teacher.

support group considered certain items designated as high level as measuring little more than rote learning. These items were identified and reclassified for the data analysis (Table 3-8).

To enhance content validity, the two classroom teachers involved in the study investigated the spread of items included in the chapter tests with regard to content. To assure that the tests were an accurate representation of what was actually taught, they eliminated items measuring content not discussed and concluded that the number of remaining questions addressing each topic was in proportion to the amount of time spent discussing that topic (See Table 3-9).

Application of Genetics commercial measure. The Genetics pretest was composed of the 15 multiple choice items and the 14 fill-in-the-blank items from the chapter test that measured low-level learning skills such as recognition or recall of information. These items were exactly the same as those administered on the posttest. The section of the Genetics chapter test geared for recognizing higher levels of learning was not administered as part of the pretest. Both the classroom and support teachers thought that testing the unfamiliar content presented in this advanced section (Punnett Square applications) before instruction began might frustrate students and introduce a negative attitude toward studying the subject matter. In addition, the support staff considered the science content pretest as a valid assessment of prior knowledge for the Punnett Square items. This decision was based on the belief that

Table 3-8

Items Teacher-Categorized by Cognitive Level (Low: Recognition/Recall or High: Application and above)

Unit		Basic Facts Pretests (commercial)	Basic Facts Posttests (commercial)	Transfer Problem Solving Pretests (commercial/researcher)	Transfer Problem Solving Posttests (commercial)	Transfer Problem Solving Postttests (teacher-constructed)
Genetics	Low Level	29	41	29	0	0
	High Level	0	0	0	30 (Punnett Square)	Nuclear Reactor (Range: 0-15)
Animal Behavior	Low Level	54	54	0	0	0
	High Level	0	0	6 (Ear Sequence) Behavior Video (Range: 0-40)	6 (Ear Sequence)	BehaviorVideo (Range: 0-40)
Solids, Liquids, Gases	Low Level	10	38	10	0	0
	High Level	0	0	0	6 (Changing Pressure)	5 (Winebottle) Balloon Demo (Range: 0-8)
Atomic Structure	Low Level	17	17	0	0	
	High Level	0	0	30 (Isotopes)	30 (Isotopes)	

Note: Ranges are indicated when student scores are calculated by totalling the number of correct relationships listed.

Table 3-9

Spread of Items Over Content of Interest for Merrill Chapter Tests

Major Topics	Percent of Instructional Time Devoted to Topic	Percent of Test Items Devoted to Topic
Genetics Unit		
Laws of Inheritance/ Punnett Square	75%	80%
DNA, RNA, Protein Synthesis	15%	10%
Mitosis/Meiosis	10%	10%
Animal Behavior		
Stimulus/Response	18%	10%
Inborn Behavior	20%	15%
Acquired Behavior	12%	15%
Social Behavior	20%	22%
Senses	30%	38%
Solids, Liquids, and Gases		
States of Matter/Kinetic Theory	18%	29%
Thermal Expansion	14%	8%
Pressure	40%	29%
Changes of State	14%	24%
Heats of Fusion and Vaporization	14%	10%
Atomic Structure		
Elements and Models	19%	19%
Atomic Structure	56%	50%
Atomic Mass/Isotopes	25%	31%

successful performance on these higher level items was directly dependent upon a knowledge and understanding of the basic concepts presented in the content pretest. This advanced section was administered as part of the posttest and regarded as a valid measure of transfer problem solving by the support staff.

Application of Animal Behavior commercial measure. The pretest and the posttest for the unit on Animal Behavior were identical and consisted of the entire chapter test. In this case, the support teachers believed that seventh graders might be familiar with parts of the content presented in the various sections and that it was important to identify this prior knowledge. With the exception of six items designated as measuring higher levels of learning, this entire instrument consisted of items requiring low-level recall of science information for successful completion.

Application of Atomic Structure commercial measure. The pretest and the posttest for the eighth grade unit on Atomic Structure were identical and each composed of 17 multiple choice items. These items were aimed at measuring recall or recognition of information. The section of this chapter test designed to measure higher learning levels was used as the measure of transfer problem solving for this unit and will be discussed in the next section.

Application of Solids, Liquids, and Gases commercial measure. The pretest for the unit on Solids, Liquids, and Gases included 10 items intended to measure relationships among facts and concepts. The eighth grade teacher and a member of the support staff thought that these items reflected the main concepts presented in this chapter and would give a quick indication of prior knowledge. Responses to these items were limited to "increases, decreases, or remains the same" and these items also composed part of the posttest. The posttest also included 28 multiple choice items and a section analyzing changes in pressure that was regarded as a valid measure of meaningful learning and will be discussed in the next section.

Pretests. The fact that the formats of the four different pretests administered in this study were not uniform is not considered a weakness of this study. Differences in chapter test formats between the 7th and 8th grade textbooks and differences in the nature of the subject matter and the extent of its coverage influenced pretest item selection. On all of these pretests, students were encouraged to make a best guess if they understood what was being discussed and to leave items blank if they had no idea of the answer.

Measures of Transfer Problem Solving

It is hypothesized that students who have meaningfully learned a topic can assimilate new, related information into their cognitive structures (Ausubel, 1968). Novak (1981) and others have put a great amount of effort into constructing measures to evaluate an individual's ability to transfer newly acquired information presented in a novel event into existing cognitive structure. Such measures of transfer problem solving should present a situation or event requiring the student to utilize content related to the unit of study but presented in a different context. These measures should require an understanding of the designated key unit concepts for successful performance and include a list of concept terms to provide limits and set parameters. Students can then attempt to explain the posed situation or event in writing by relating their understanding of the unit concepts to the event. If the concepts have not been learned meaningfully, student explanations will not show a relationship between the unit concepts and the specified event.

Although some worksheets and cognitive test items from the Merrill program were intended to measure application of new knowledge to novel situations, the support teachers who examined these materials did not always agree that items included in the section Using Concepts were adequate or challenging enough to be used as valid measures of this dependent variable. Therefore, additional measures were constructed by the researcher, with help from the support teachers and the eighth grade classroom teacher participating in this study, according to guidelines presented by Novak (1981).

Higher level Genetics measures. The Punnett Square questions mentioned earlier that were included in the commercially-produced Genetics chapter test were designated a valid measure of meaningful learning by the support teachers. These individuals agreed that successful completion of these items required that students had a basic understanding of the concepts presented in the text, could form judgments about these concepts, and could apply them to new situations. In addition, seventh graders completed a researcher-constructed measure presenting a scenario

requiring them to describe the possible consequences of a nuclear power plant disaster.

Higher level Animal Behavior measures. With the exception of six items evaluating student knowledge of the hearing process in the human ear, the chapter test from the unit on Animal Behavior did not include items considered valid measures of transfer problem solving. An additional measure was constructed by the researcher in which students observed 14 isolated video segments of various animal behaviors and attempted to explain these behaviors using accurate and appropriate terminology. These segments were chosen to illustrate examples of such behaviors as acquired or inborn behavior, territoriality, and use of pheromones.

Higher level Solids, Liquids, and Gases measures. Three transfer problem solving measures were considered appropriate for the eighth grade unit on Solids, Liquids, and Gases. One of these was from the publisher-constructed chapter test and evaluated student knowledge of changes in pressure. A second measure was the Winebottle Test first used by Novak and staff (1981) in their study of middle school concept mappers. The Winebottle Test was designated a valid measure of meaningful learning in this earlier study and is considered a classic model for construction of new transfer problem solving measures. For the Winebottle Test, students were presented with an event, a cork popping out of a warmed, empty wine bottle, and required to explain the event using related concepts such as expansion and kinetic energy that they had just studied. For the third higher level measure in the Solids, Liquids, and Gases Unit, students were asked to observe and react to a demonstration illustrating changes in pressure within a system. A partially inflated balloon was placed inside of a bell jar attached to a vacuum pump. As air was drawn out of the bell jar, and the balloon expanded, students were asked to carefully observe what was happening and use appropriate terminology to describe their observations.

Higher level Atomic Structure measure. The transfer problem solving measure for the unit on Atomic Structure required students to draw isotopes of atoms they had not formally studied. This measure was a slight modification of that included with the chapter test. Examples of all problem solving measures are included as Appendices D, E, F, and G.

Pretests. The transfer problem solving measures for the units on Animal Behavior and Atomic Structure were administered as pretests before any instruction on these units was given. Identical pretests were not given for the Genetics or Solids, Liquids, and Gases transfer problem solving measures. The classroom and support teachers considered it acceptable to use the science content pretests as pretests for these more difficult transfer problem solving measures. This decision was based upon the assumption that successful performance on these transfer problem solving measures would depend directly upon knowledge and understanding of the basic concepts presented in the science content pretests.

Content validity for researcher-constructed transfer problem solving measures. The researcher-constructed transfer problem solving measures for Genetics, Animal Behavior, and Solids, Liquids and Gases did not consist of a specific number of test items but were open ended and could satisfactorily be completed with a number of statements demonstrating conceptual relationships. To determine the content validity of these measures or how well and in what proportions they represented the appropriate universe of unit content, concept maps were constructed for each unit by the classroom teachers and used as a basis for content evaluation. The transfer problem solving measures were discussed with reference to these staff-prepared maps of the topics, skills, and abilities considered representative of the content area being studied. The project staff agreed that correct responses to these transfer problem solving measures could be drawn from propositional statements distributed evenly throughout these maps (See Figures 3-1, 3-2, 3-3, and 3-4).

Measures of Attitudes Toward the Instructional Experience

Two separate 5-point Likert scales were used to evaluate student attitudes toward the learning strategies employed in this study. One scale was constructed to assess student attitudes toward concept mapping (14 items) and the other to assess student attitudes toward cooperative learning (16 items). Items were grouped into categories on the basis of how they affected a student's thinking, feeling, or acting about the particular strategy. The Thinking-Feeling-Acting Questionnaire for evaluating concept mapping in this study was adapted from a measure developed by Heinze-Fry and Novak (1990) for use with college biology students, which consisted of 25 statements generated from student comments to open-ended questions. It was adapted by this researcher to accommodate middle school students and the unique characteristics of this study. A similar measure following the same format and theme as the concept mapping measure was researcher-constructed for cooperative learning. These measures are included as Appendices H and I.

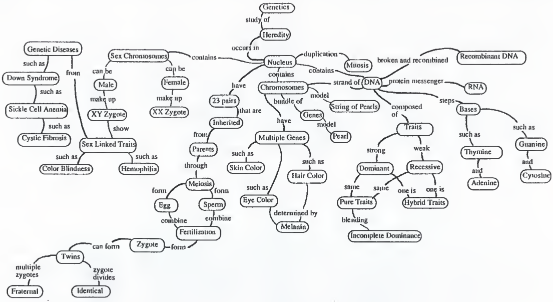


Figure 3-1. Teacher constructed concept map for the unit on Genetics.

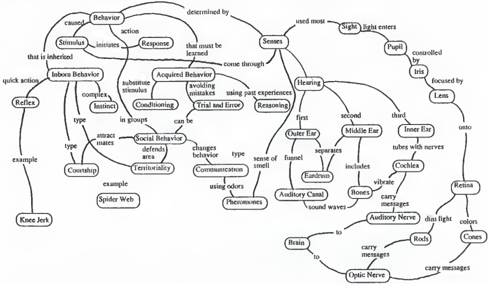


Figure 3-2. Teacher constructed concept map for the unit on Animal Behavior.

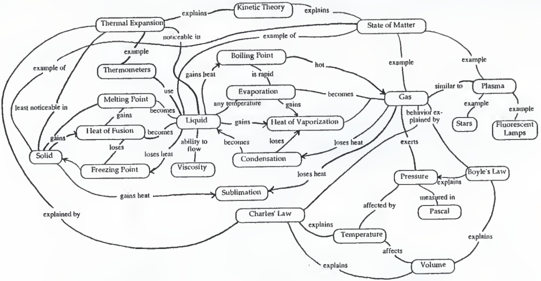


Figure 3-3. Teacher constructed concept map for the unit on Solids, Liquids, and Gases.

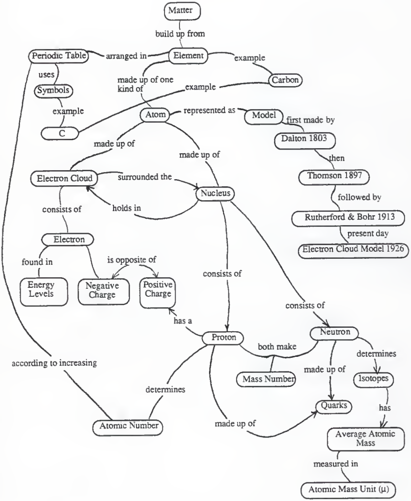


Figure 3-4. Teacher constructed concept map for the unit on Atomic Structure.

Students working in cooperative learning groups without mapping completed the cooperative learning measure only. Students working on concept maps independently completed the concept mapping measure only. Students constructing concept maps in cooperative learning groups completed both measures.

Three members of the teacher support group assessed the content validity of these two attitudinal measures. They agreed that the items categorized as indicators of thinking, feeling, or acting processes were appropriately placed and in proportion to the overall emphases of the study. It was their judgment that these measures would provide a fair indication of how seventh and eighth graders thought and felt about these two strategies.

Analyses were conducted to determine the reliability of the attitude measures used in this study. To determine the consistency of responses across items, the Cronbach's alpha reliability coefficient was estimated. The reliability coefficient for the entire cooperative learning attitudinal instrument was .72. When the "thinking" and "feeling" subsections were analyzed, the reliability for the cooperative "thinking" subsection was .53 and the reliability for the cooperative "feeling" subsection was .39. The reliability coefficient for the entire concept mapping attitudinal instrument was .37. When the subsections were analyzed, the reliability coefficient for the mapping "thinking" subsection was .61 and the reliability for the mapping "feeling" subsection was .10.

Procedure

Selection of sections. The science teachers at both grade levels each selected two science textbook units on topics that students were unlikely to have encountered in depth in prior science instruction. These units included supplementary materials for mastery and evaluation. All students at each grade level, regardless of learning mode, were responsible for mastering the same unit content. The researcher randomly assigned (a) one section in which students constructed concept maps of the material independently, (b) a second section in which students covered the material in cooperative learning groups without concept mapping, and (c) a third section in which students constructed concept maps of the material in cooperative learning groups.

Learning to Learn instruction. All students initially received a uniform introduction to the Learning to Learn activities of Novak (1980). Pilot studies have shown that this 1- or 2-period introduction to the nature of concepts and meaningful learning can avoid confusion in subsequent concept mapping instruction (Novak et al., 1983). This introduction was presented to all students in all sections so that it could not be interpreted as a confounding variable.

A brief example of how concepts can be organized hierarchically was also presented, but only to the two groups of students at each grade level who would be constructing concept maps either individually or cooperatively. This procedure is considered part of actual concept map construction (Novak & Gowin, 1984). This presentation included the idea that a variety of hierarchical possibilities can exist for a group of concepts depending upon an individual's understanding or interpretation of these concepts. This example was the same for students constructing concept maps at both grade levels and unrelated to the science content introduced later.

Group selection. Teachers selected groups of three members each for the sections working cooperatively. Students were first ranked from highest to lowest using base scores calculated by the appropriate teacher. These scores were determined from science performance prior to the time of this study. Group composition included one high, middle, and low performer as indicated by these base scores. Students were not aware of the procedure used for selection of cooperative learning groups.

The first cooperative group was formed by selecting the student at the top of the list, the student at the bottom of the list, and the student in the middle of the list. The second group was composed of the student second from the top, the student second from the bottom, and a middle student one up or one down from the first middle selection. Students were thus assigned to groups unless all members were of the same sex or group composition did not reflect the ethnic composition of the class. In these cases, the teacher moved one place up or down the list to make the group selections and maintained heterogeneity with respect to gender, ethnicity, and achievement (Johnson et al., 1986). Group composition was also slightly readjusted if two best friends or worst enemies were assigned to the same group or if an isolated student needed to be placed with supportive individuals. Teachers found this grouping procedure was facilitated by using individual name cards that could be shuffled until group selection seemed satisfactory.

Introduction to learning strategies. Students who constructed concept maps independently received an introduction to concept mapping theory and construction followed by a practice exercise using guidelines provided by Novak and Gowin (1984). Students who worked in cooperative learning groups to master the unit content without concept mapping were introduced to the organization and expectations of working cooperatively using examples and practice exercises suggested by Johnson and Johnson (1987) and Cohen (1986). Students who constructed concept maps in cooperative learning groups to master the unit content received introductory instruction and practice in both concept mapping and cooperative learning. These introductory explanations and examples required two class periods and were the same for students at both grade levels and unrelated to the science content introduced later.

Teacher instruction. Each teacher explained and clarified all specific procedures and expectations for each treatment group. Students working cooperatively were reminded that their major group task was to make sure all group members were prepared to be successful on measures of individual achievement. Forms of materials, reward, and goal interdependence were established. Teachers explained that groups would be monitored and data for feedback collected and that processing time would be provided to discuss how well collaborative skills were being used.

The collaborative skills stressed were listening carefully to one another, encouraging participation of all members, criticizing constructively, and not agreeing unless logically persuaded to do so when challenging worksheet answers or conceptual placements on a concept map. T-Charts (Johnson et al., 1986) (See Appendix C) were used to discuss how these skills could effectively be practiced. These charts provide a format for demonstrating behaviors that reflect correct usage of certain collaborative skills.

Students were informed that a facilitator had been selected by the teacher from each group. It was explained that these individuals were not leaders, as leadership responsibilities were shared among all group members, but chosen to help the teacher be assured that all students participate and derive the maximum benefit from group involvement.

Students working cooperatively were informed of their individual base scores in a manner that assured privacy and were told that up to five bonus points would be awarded to all members of every group in which each individual achieved his/her base score or better on measures of individual achievement. In addition, the maximum number of bonus points would not be awarded unless the teacher believed that the group had practiced their collaborative skills conscientiously. Students working independently were also informed of their base scores and told that bonus points were available to them if they achieved their base scores or better on the individual achievement test.

Teachers then gave introductory lessons on the unit content. Following this instruction, each teacher distributed a list of 15 to 20 key concepts with definitions that the teacher had discussed and identified as critical to understanding the unit. These terms were among those emphasized in the text and selected with both the hierarchical and cross-link elements of a concept map in mind. All students were asked to study these key terms and carefully read related textual information.

Hierarchical organization of terms. Students constructing concept maps independently used scissors to cut out the 15 to 20 concept names and accompanying definitions from the handout and organized them hierarchically with clusters where appropriate. Students working in cooperative groups without concept mapping began to complete a single packet of worksheets that they would all be required to sign upon completion signifying their agreement and understanding of the content. Students constructing concept maps in cooperative learning groups first individually cut out and organized the 15 to 20 concept names hierarchically, then met with their group members before submitting a single, final, signed conceptual arrangement.

Completion of concept maps or content packet. Students working with concept maps selected an additional 10 or more conceptual terms from reading material, class discussions, or personal experiences, and recorded these additional concepts and their definitions onto paper. They then received sheets of rectangular stickers with the original 15 to 20 concept names in large print and as many blank rectangular stickers as were needed to record their additional 10 or more conceptual terms. Students constructing concept maps then cut out all the conceptual terms and proceeded to organize them on large sheets of white paper.

Students working on concept maps independently integrated the additional 10 conceptual terms into their existing hierarchies, reorganizing and clustering where appropriate. Students were not yet allowed to permanently affix the conceptual terms onto the paper. The teachers monitored individual work by clarifying concepts, raising questions, and encouraging summarization, elaboration, and evaluation of important concepts and propositions. Students in this condition were not allowed to discuss conceptual arrangements with peers any more than in a traditional setting. Students completed their concept map organization, affixed the rectangular pieces onto the large piece of paper, and formed propositions by drawing and labelling connecting lines. Students were encouraged to find "cross-links" connecting related concepts from different hierarchical portions of the map.

Students working in cooperative learning groups without mapping continued to work on their packets. The teachers monitored these groups by clarifying concepts, raising questions, and encouraging summarization, elaboration, and evaluation of important ideas. Appropriate criticism of another's responses and subsequent negotiation were encouraged. The packet of materials was completed with group consensus.

Students working on concept maps in cooperative learning groups reached agreement on which additional conceptual terms merited inclusion in their concept map and at what level. The teachers monitored these groups by clarifying concepts, raising questions, and encouraging summarization, elaboration, and evaluation of important concepts and propositions. Each cooperative group worked together to complete its concept map organization, affixed the rectangular pieces onto the large piece of paper, and drew and labelled propositional lines. Appropriate criticism of conceptual placements, another's responses, and subsequent negotiation were encouraged. Students were encouraged to find "cross-links" connecting related concepts from different hierarchical portions of the map. The concept maps were completed with group consensus.

Data Collection and Scoring

Procedures for test administration were uniform for all classes at both grade levels. Data for the measures of science achievement and transfer problem solving ability were collected at the end of each 3-week unit of study in science. Data from the attitudinal measures were collected once at the completion of the last 3-week unit.

All measures of science content were paper and pencil tests that could be completed in one class period. Measures of transfer problem solving focused upon a particular event that could be represented by a lab demonstration, segment of videotape, or a written explanation.

Credit was accumulated for the transfer problem solving measures on the basis of the quality and quantity of recorded propositional statements. Some of these measures required a well-defined set of appropriate responses, and points were awarded on the basis of how many of these elements were present. Others were more conducive to a wide range of responses and points were accumulated on the basis of the number of valid conceptual relationships listed.

When the Winebottle Test was administered in the 1981 study (Novak and staff), points were accumulated on the basis of the number of valid conceptual relationships listed. For example, a statement reflecting the fact that the air in a warmed, closed container expands would receive one point. A relationship such as this was considered analogous to a propositional component of a concept map. In this study, a holistic approach to grading the Winebottle question was adopted. Project staff decided that an acceptable answer to this question should include certain components and recommended awarding a maximum of five points for student responses including this information. Slightly less elaboration merited a score of four or three points respectively, two points were awarded if the basic idea that particles expand and the cork pops off the bottle was included, and one point if only one or two simple facts were listed.

The grading procedures used for the transfer problem solving measures on Genetics and Animal Behavior were also based upon the quantity and quality of the propositional relationships listed. However, these measures allowed for acceptance of a large number of key concepts, and therefore a larger number of conceptual relationships, than the Winebottle Test or balloon demonstration. For this reason, members of the support staff suggested an open-ended system of tallying relationships for these measures rather than using a holistic approach. However, as staff members began evaluating these measures, they discovered that each measure presented its own unique set of problems that needed to be addressed.

One problem presented by the Genetics measure was the difficulty distinguishing between a short, less detailed propositional statement and a more complete response carefully elaborating one particular point. A distinction also needed to be made between valid responses using science vocabulary that accompanied the transfer problem solving measure and an accurate, related statement that contained non-scientific terms. Members of the support staff felt that evaluation of this measure should award the use of conceptual terms listed with the question and acquired from the textbook, and that the use of a wide range of these terms was preferred. Therefore, a bonus system was implemented based upon the use of the 16 conceptual terms that accompanied the Genetics measure. One point was added to the relationships score if 4 to 7 terms were included. Two points were added for the use of 8 to 11 terms and a maximum of 3 bonus points was added if 12 to 16 textbook terms were used. No credit was given for using less than 4 terms. This bonus system was not implemented until after this measure had been administered.

In the case of the Genetics question, students were expected to record valid conceptual statements applicable to a single event, a damaged nuclear power plant. The transfer problem solving measure for Animal Behavior which was composed of 14 separate video segments required a different approach for evaluation. For the Animal Behavior measure, each of the 14 video segments was evaluated separately and the total number of points recorded. A list of 21 conceptual terms accompanied this measure. After a single video clip was shown, students were asked to describe what they saw using as many appropriate terms from the list as possible as well as any other scientific terms that applied. Students were allowed time between segments to respond.

In order to evaluate student responses for the Animal Behavior measure and insure that the most appropriate terms were correctly used, a scoring grid was constructed to identify which of the 21 terms to include for each video segment. Members of the support staff identified key terms and secondary terms for each video selection and agreed that a maximum of three points could be earned for each selection. Key terms were given a value of 2 points while secondary terms earned 1 point. However, inclusion of at least one key term was required for full credit. Therefore, no more than 2 points were awarded for secondary answers regardless of how many were used. A student who successfully identified two key terms for a given video segment earned 3 points whether he/she included secondary terms or not. No negative points were issued for any terms that were inappropriately identified or used. The scoring grid used for this measure is included as Appendix K.

Project staff responsible for scoring the measures used in this study followed a procedure of first meeting to discuss the evaluation criteria for the particular measure, and then separating to score student responses independently. An example of the effectiveness of this system is indicated by a comparison of the raters' scores for the balloon demonstration. Two science teachers scored 64 responses to this question. Recorded scores were identical in 28 cases, differed by one point in 27 cases, and differed by more than one point in 9 cases.

Evaluation of Concept Maps and Learning Packets

A variety of methods have been devised to assess concept maps quantitatively (Novak & Gowin, 1984; Novak et al., 1983). Points have been awarded for (a) the number of valid propositions listed, (b) the degree of hierarchy or number of levels identified in the constructed map, (c) the amount of branching or degree of differentiation among concepts, and (d) the number of valid cross links or meaningful connections between map subdivisions. In some studies, project staff first constructed an ideal or "model" map. Student maps were then compared to the model using the criteria listed above and the resulting score was recorded as a percent ratio (Novak & staff, 1981). In all scoring procedures, the major emphasis has been on a downward, outwardly branching flow of ideas originating with a few superordinate concepts and widening into a range of subordinate concepts or examples.

In previous experiences with middle school students constructing concept maps for the first time, this researcher had difficulties applying established scoring procedures to student maps. Hierarchies were often difficult to distinguish and examples of concepts were rarely brought down to the most specific or lowest levels of student maps. For this study, because the minimum number of concepts to be mapped was assigned, even counting the number of valid propositions did not seem to be an important indicator of academic growth.

Members of the support staff decided that a realistic student goal for this study was successful construction and subsequent understanding of a completed, labeled, generally correct concept map. This understanding was determined by the staff's ability to correctly read through and explain each completed concept map from top to bottom following a logical continuum from general to more specific, subordinate concepts. These criteria were based upon the fact that the major emphasis of established scoring criteria has been on the hierarchical organization of concepts.

If these criteria were met, the map was considered acceptable and received a grade of 85%. If propositional relationships were incorrect or unlabeled, if the assigned number of required concepts was not included, or if very little branching was observed, the map was considered less than acceptable and points were deducted from the 85% score. If the number of concepts and labeled propositions was more than required, or if valid cross-links were formed linking map subdivisions, or if other creative aspects were included, the map was regarded as more than acceptable and additional points were added to the 85% score. The maximum score that could be awarded was 100% and the minimum score for a "completed" map was 70% (See Appendix J).

At least two members of the support staff evaluated all student maps. They were familiar with both the appropriate unit content and the strategy of concept mapping. These evaluators were also asked to look carefully at the types of connecting words used in propositional linkages and note the number of cross-links included. Novak and staff (1981) found that if map scoring criteria were clearly established, and if raters had a thorough understanding of mapping procedures and the subject area of interest, scores whould be consistent from rater to rater. A comparison of raters' scores for this study from the Genetics Unit show that, with one exception, all concept map scores differed by less than four points. Raters' scores were averaged and this average was recorded as the student score.

Learning packets completed by students working cooperatively without mapping were checked for completion and accuracy by members of the support staff. Generally, the information required for completing these items was readily available in the student text.

Data Analysis

Individual class means were calculated for all pre and post measures for each of the three treatments at both grade levels to determine whether differences in low-level achievement, transfer problem solving ability, or attitudes toward the instructional experience could be attributed to any of the independent variables. Data for each grade and for each content unit were analyzed separately.

At each grade level, an analysis of variance (ANOVA) was used to compare the pretest mean scores of the three groups before each unit of study was presented. Analyses of covariance (ANCOVAs) were the data analysis procedures used to compare adjusted posttest scores on measures of science content and transfer problem solving. In these 3 x 2 factorial ANCOVAs, the independent variables were treatment and student gender. The gender variable was introduced into the model to control for extraneous variation that might have reduced the opportunity to detect treatment effects. It also allowed for the possibility of detecting a gender x treatment interaction.

Items from each of the attitudinal measures were categorized into "thinking" and "feeling" subsections. Independent samples t-tests were the data analyses procedures used to compare groups of students experiencing one of these strategies (concept mapping *or* cooperative learning) with groups of students experiencing both of these strategies (concept mapping *and* cooperative learning).

The concept mapping evaluation procedure designed for this study was used to obtain data from completed concept maps. Because each treatment group constructed different numbers of maps, direct comparisons among maps were difficult. It was decided that concept maps constructed independently might be compared with concept maps constructed cooperatively if data were plotted on axes that varied in proportion to the number of maps constructed by each treatment group.

Comments about these graphic representations are included in Chapter IV.

CHAPTER IV
RESULTS

The hypotheses for this study were related to the central theme that students constructing concept maps in cooperative learning groups would perform better on cognitive and attitudinal measures than students mapping independently or students working cooperatively without mapping. Specifically, these dependent variables focused on (a) measures of low-level recall science content knowledge (hypothesis 1), (b) measures of high-level transfer problem solving ability in science (hypothesis 2), and (c) measures of attitudes toward the instructional experience (concept mapping or cooperative learning) (hypothesis 3) (See Tables 3-4 and 3-5).

Analyses of variance (ANOVAs) were the statistical analyses procedures conducted to determine the pretreatment status of subjects, and analyses of covariance (ANCOVAs) were conducted to investigate the effects of treatment on the dependent variables. For the four major content units (Genetics, Animal Behavior, Solids, Liquids, and Gases, and Atomic Structure), ANCOVAs were conducted for commercially-produced measures of low-level science content knowledge and commercial and researcher-constructed measures of high-level transfer problem solving ability in science. For the attitudinal measures, independent samples t-tests were conducted on categories of items to examine the effects of concept mapping and cooperative learning on student attitudes toward each of the respective treatments.

Examination of Pre-Treatment Status of Groups

A series of 3 x 2 (Treatment x Gender) analyses of variance (ANOVAs) were conducted on the pretests administered for each of the four science content units. These analyses indicated that no significant differences existed among the three groups, suggesting that the groups could be considered equivalent on these particular measures before treatment began (See Appendix L).

Analyses of Measures of Recall or Low-Level Science Content Knowledge (Hypothesis 1)

Commercial measures of low-level science content knowledge were administered to all students as pretests and again as posttests at the end of each 3-week unit of study. Means and standard deviations for the gender and treatment groups are shown in Tables 4-1 to 4-4 for the four content units.

For each content area (Genetics, Animal Behavior, Solids, Liquids, and Gases, and Atomic Structure), a 3 x 2 (Treatment x Gender) analysis of covariance (ANCOVA) was conducted to determine whether there were significant differences among the treatments. The independent variables in these ANCOVAs were gender (with 2 levels) and treatment (with 3 levels); the appropriate pretest served as covariate, and the unit posttest served as dependent variable.

Table 4-1

Means (and Standard Deviations) for Pretest and Posttest Scores on Genetics Recall Science Content Knowledge

	males			females		
Treatment Groups	n	Pre	Post	n	Pre	Post
Mapping Only	9	6.667 (5.408)	34.000 (5.454)	13	6.000 (4.359)	30.615 (5.635)
Cooperative Only	10	5.900 (3.348)	35.000 (3.367)	12	4.750 (3.108)	32.000 (5.099)
Mapping and Coop	7	5.143 (2.854)	34.286 (3.450)	12	7.750 (4.595)	33.250 (5.083)

Note. Number of Pretest items = 29; Number of Posttest items = 41

Table 4-2

Means (and Standard Deviations) for Pretest and Posttest Scores on Animal Behavior Recall Science Content Knowledge

	males			females		
Treatment Groups	n	Pre	Post	n	Pre	Post
Mapping Only	9	30.333 (14.283)	46.222 (9.121)	14	21.500 (11.700)	44.786 (7.029)
Cooperative Only	10	24.100 (12.360)	48.500 (3.894)	12	24.000 (6.915)	46.250 (6.412)
Mapping and Coop	9	24.889 (11.005)	46.000 (8.047)	12	25.083 (9.150)	46.167 (6.926)

Note. Number of Pretest items = 54; Number of Posttest items = 54

Table 4-3

Means (and Standard Deviations) for Pretest and Posttest Scores on Solids, Liquids, and Gases Recall Science Content Knowledge

	males			females		
Treatment Groups	n	Pre	Post	n	Pre	Post
Mapping Only	13	7.000 (1.958)	28.077 (6.512)	9	6.222 (3.073)	31.778 (5.674)
Cooperative Only	11	6.909 (2.663)	29.818 (6.145)	11	5.600 (2.271)	29.091 (4.158)
Mapping and Coop	12	5.636 (2.803)	28.083 (4.420)	10	6.000 (1.563)	29.000 (5.207)

Note. Number of Pretest items = 10; Number of Posttest items = 38

Table 4-4

Means (and Standard Deviations) for Pretest and Posttest Scores on Atomic Structure Science Content Knowledge

	males			females		
Treatment Groups	n	Pre	Post	n	Pre	Post
Mapping Only	13	5.500 (2.780)	14.077 (3.353)	7	5.000 (2.062)	15.714 (1.113)
Cooperative Only	11	8.000 (4.074)	14.545 (1.968)	11	5.167 (2.758)	14.182 (2.040)
Mapping and Coop	12	5.455 (1.968)	14.583 (2.109)	10	4.667 (2.872)	14.600 (2.271)

Note. Number of Pretest items = 17; Number of Posttest items = 17

No significant between treatment mean effects were found for the Solids, Liquids, and Gases measure of low-level science content knowledge or the Atomic Structure measure of low-level science knowledge. For the Genetics measure, however, significant differences existed between male and female performance (See Table 4-5). The adjusted means indicated that males (M adj 34.54) outperformed females (M adj 31.90). The summary tables for these ANCOVAs are presented in Tables 4-5 to 4-8. With the exception of the ANCOVA conducted for the Atomic Structure posttest, pretest scores were significantly related to posttest scores.

An assumption of the ANCOVA procedure is that there are no significant interactions between the covariate and the main effects, gender and treatment. This assumption was tested by repeating the analysis using a general linear model that included terms for Pretest x Treatment and Pretest x Gender. Neither of these interactions was significant for any of the ANCOVAs conducted for the commercial measures from the three academic units in Genetics; Solids, Liquids, and Gases; and Atomic Structure. However, for the Animal Behavior low-level posttest, a three-way interaction (Pretest x Treatment x Gender) was statistically significant (See Table 4-6). Figure 4-1 shows the nature of this interaction.

From the Genetics low-level measure of science content, for Pretest x Treatment, $F = 2.62$ with $p = .08$ at 2, 51 df. For Pretest x Gender, $F = .20$ with $p = .66$ at 1, 51 df. From the Solids, Liquids, and Gases measure, for Pretest x Treatment, $F = 1.87$ with $p = .16$ at 2, 52 df. For Pretest x Gender,

Table 4-5

3 x 2 (Treatment x Gender) ANCOVA for Genetics Low-Level Commercial Posttest

Source	df	SS	F	Pr>F
Pre	1	374.3930	21.21	0.0001*
Trt	2	38.3231	1.09	0.3447
Sex	1	104.7632	5.94	0.0180*
Trt*Sex	2	1.2816	0.04	0.9644

*$p \leq .05$

Table 4-6

3 x 2 (Treatment x Gender) ANCOVA for Animal Behavior Low-level Commercial Posttest

Source	df	SS	F	Pr>F
Pretest	1	1443.4277	60.91	0.0001*
Trt	2	17.9081	0.38	0.6871
Sex	1	23.7902	1.00	0.3208
Pretest*Trt	2	0.2722	0.01	0.9943
Pretest*Sex	1	36.2716	1.53	0.2214
Pretest*Trt*Sex	2	168.0026	3.54	0.0358*
Trt*Sex	2	225.2493	4.75	0.0126*

*$p \leq .05$

Table 4-7

3 x 2 (Treatment x Gender) ANCOVA for Solids, Liquids, and Gases Low-Level Commercial Posttest

Source	df	SS	F	Pr>F
Pre	1	125.7236	4.57	0.0369*
Trt	2	4.1340	0.08	0.9277
Sex	1	25.0118	0.91	0.3445
Trt*Sex	2	67.5984	1.23	0.3005

*$p \leq .05$

Table 4-8

3 x 2 (Treatment x Gender) ANCOVA for Atomic Structure Low-Level Commercial Posttest

Source	df	SS	F	Pr>F
Pre	1	10.5538	1.87	0.1766*
Trt	2	5.2735	0.47	0.6285
Sex	1	5.0246	0.89	0.3490
Trt*Sex	2	10.9357	0.97	0.3851

*$p \leq .05$

F = .76 with p = .39 at 1, 52 df. From the Atomic Structure measure, for Pretest x Treatment, F = .29 with p = .75 at 2, 49 df. For Pretest x Gender, F = .23 with p = .64 at 1, 49 df.

Analyses of Measures of High-Level Transfer Problem Solving Ability in Science (Hypothesis 2)

Both commercial and researcher-constructed measures of high-level transfer problem solving ability in science were administered to all students as pretests and again as posttests at the end of each 3-week unit of study. Means and standard deviations for the gender and treatment groups are shown in Tables 4-9 to 4-17.

For each content area (Genetics, Animal Behavior, Solids, Liquids, and Gases, and Atomic Structure), 3 x 2 (Treatment x Gender) analyses of covariance (ANCOVAs) were conducted to determine whether there were significant differences among the treatments. The independent variables in these ANCOVAs were gender (with two levels) and treatment (with three levels); the appropriate pretest served as covariate, and the unit posttest served as dependent variable.

No significant mean effects were found on any of the ANCOVAs conducted for the three measures of transfer problem solving ability from the Solids, Liquids, and Gases Unit or on the ANCOVA conducted for their combined scores. For the Genetics Unit, however, significant differences

Table 4-9

Means (and Standard Deviations) for Pretest and Posttest Scores on Genetics Commercially-Produced Transfer Problem Solving Measure

	males			females		
Treatment Groups	n	Pre	Post	n	Pre	Post
Mapping Only	9	6.667 (5.408)	26.000 (3.574)	13	6.000 (4.359)	24.308 (3.146)
Cooperative Only	10	5.900 (3.348)	26.800 (1.819)	12	4.750 (3.108)	23.417 (4.274)
Mapping and Coop	7	5.143 (2.854)	24.857 (2.968)	12	7.750 (4.595)	25.000 (2.629)

Note. Number of Pretest items = 29; Number of Posttest items = 30

Table 4-10

Means (and Standard Deviations) for Pretest and Posttest Scores on Genetics Researcher-Constructed Transfer Problem Solving Measure

	males			females		
Treatment Groups	n	Pre	Post	n	Pre	Post
Mapping Only	9	6.667 (5.408)	6.889 (4.285)	13	6.000 (4.359)	4.615 (2.293)
Cooperative Only	10	5.900 (3.348)	4.400 (2.271)	12	4.750 (3.108)	4.583 (2.234)
Mapping and Coop	7	5.143 (2.854)	6.143 (3.388)	12	7.750 (4.595)	5.000 (2.449)

Note. Number of Pretest items = 29; Number of Posttest items = 15

Table 4-11

Means (and Standard Deviations) for Pretest and Posttest Scores on Animal Behavior Commercially-Produced Transfer Problem Solving Measure

	males			females		
Treatment groups	n	Pre	Post	n	Pre	Post
Mapping Only	9	3.333 (2.828)	4.778 (1.986)	14	2.214 (2.723)	4.500 (1.912)
Cooperative Only	10	2.300 (2.751)	4.900 (1.792)	12	2.167 (2.038)	4.250 (2.006)
Mapping and Coop	9	3.556 (2.351)	5.444 (1.130)	12	1.500 (1.883)	4.333 (2.015)

Note. Number of Pretest items = 6; Number of Posttest items = 6

Table 4-12

Means (and Standard Deviations) for Pretest and Posttest Scores on Animal Behavior Researcher-Constructed Transfer Problem Solving Measure

	males			females		
TreatmentGroups	n	Pre	Post	n	Pre	Post
Mapping Only	9	7.778 (6.320)	21.333 (7.810)	14	3.429 (5.417)	18.571 (6.501)
Cooperative Only	10	4.100 (4.175)	23.600 (6.883)	12	3.083 (2.109)	19.500 (6.516)
Mapping and Coop	9	5.000 (5.099)	16.667 (4.583)	12	5.167 (5.474)	23.167 (6.847)

Note. Number of Pretest items = 40; Number of Posttest items = 40

Table 4-13

Means (and Standard Deviations) for Pretest and Posttest Scores on Solids, Liquids, and Gases Commercially-Produced Transfer Problem Solving Measure

	males			females		
Treatment Groups	n	Pre	Post	n	Pre	Post
Mapping Only	13	7.000	2.846	8	6.222	3.125
		(1.958)	(1.068)		(3.073)	(0.641)
Cooperative Only	11	6.909	4.000	11	5.600	3.364
		(2.663)	(0.894)		(2.271)	(1.206)
Mapping and Coop	12	5.636	3.167	9	6.000	3.778
		(2.803)	(0.835)		(1.563)	(1.093)

Note. Number of Pretest items = 10; Number of Posttest items = 6

Table 4-14

Means (and Standard Deviations) for Pretest and Posttest Scores on Solids, Liquids, and Gases Researcher-Constructed Transfer Problem Solving Measure (Winebottle)

	males			females		
Treatment Groups	n	Pre	Post	n	Pre	Post
Mapping Only	13	7.000	2.077	8	6.222	3.125
		(1.958)	(1.239)		(3.073)	(1.217)
Cooperative Only	11	6.909	2.591	11	5.600	2.273
		(2.663)	(1.136)		(2.271)	(1.034)
Mapping and Coop	12	5.636	2.667	9	6.000	2.778
		(2.803)	(1.094)		(1.563)	(1.502)

Note. Number of Pretest items = 10; Number of Posttest items = 5

Table 4-15

Means (and Standard Deviations) for Pretest and Posttest Scores on Solids, Liquids, and Gases Researcher-Constructed Transfer Problem Solving Measure (Bell Jar)

	males			females		
Treatment Groups	n	Pre	Post	n	Pre	Post
Mapping Only	13	7.000	4.923	9	6.222	4.667
		(1.958)	(1.188)		(3.073)	(1.803)
Cooperative Only	11	6.909	5.091	11	5.600	4.818
		(2.663)	(1.375)		(2.271)	(1.537)
Mapping and Coop	11	5.636	4.273	10	6.000	4.900
		(2.803)	(0.786)		(1.563)	(1.287)

Note. Number of Pretest items = 10; Number of Posttest items = 8

Table 4-16

Means (and Standard Deviations) for Pretest and Posttest Scores on Solids, Liquids, and Gases Total Battery of Commercial and Researcher-Constructed Transfer Problem Solving Measures

	males			females		
Treatment Groups	n	Pre	Post	n	Pre	Post
Mapping Only	13	7.000	9.846	8	6.222	11.375
		(1.958)	(1.962)		(3.073)	(2.280)
Cooperative Only	11	6.909	11.682	11	5.600	10.455
		(2.663)	(2.250)		(2.271)	(2.970)
Mapping and Coop	11	5.636	10.045	9	6.000	11.333
		(2.803)	(1.739)		(1.563)	(2.411)

Note. Number of Pretest items = 10; Number of Posttest items = 19

Table 4-17

Means (and Standard Deviations) for Pretest and Posttest Scores on Atomic Structure Commercially-Produced Transfer Problem Solving Measure

	males			females		
Treatment Groups	n	Pre	Post	n	Pre	Post
Mapping Only	13	5.500 (2.780)	18.923 (7.911)	7	5.000 (2.062)	27.714 (3.498)
Cooperative Only	11	8.000 (4.074)	19.909 (9.159)	11	5.167 (2.758)	21.818 (8.460)
Mapping and Coop	12	5.455 (1.968)	20.167 (7.590)	10	4.667 (2.872)	19.700 (9.615)

Note. Number of Pretest items = 30; Number of Posttest items = 30

existed between male and female transfer problem solving skills on the commercial measure (See Table 4-18). The adjusted means indicated that males (M adj 25.97) outperformed females (M adj 24.20). No significant differences were found for the researcher-constructed transfer problem solving measure from the Genetics Unit.

An ANCOVA conducted for the behavior video transfer problem solving posttest revealed a treatment by sex interaction effect that was statistically significant (See Table 4-21). To examine which differences contributed to the significance of the interaction terms, six post hoc pairwise comparisons were performed. To maintain the experiment-wise Type I error rate, a Bonferroni adjustment was done. The adjusted probability level was .0083. The results indicated that the adjusted mean scores on the video posttest for males exposed to mapping and cooperative learning (M =16.39) were significantly lower than the mean scores of the males exposed to only cooperative learning (M = 19.18). The remaining pairwise comparisons resulted in no significant differences.

For the Atomic Structure commercial transfer problem solving posttest, significant differences existed between male and female problem solving skills (See Table 4-26). The adjusted means indicated that females (M adj 23.57) outperformed males (M adj 19.02) on this high-level measure.

The summary tables for these ANCOVAs are presented in Tables 4-18 to 4-26. With the exception of the ANCOVAs conducted for the Solids, Liquids, and Gases transfer problem solving measure, pretest scores were significantly related to posttest scores.

The ANCOVA assumption of no significant interaction of covariate and main effects (gender and treatment) was tested for these measures of transfer problem solving in science. The analyses were repeated using a general linear model that included terms for Pretest x Treatment and Pretest x Gender. Neither of these interactions was significant for any of the ANCOVAs conducted for the measures of transfer problem solving ability in science.

From the Genetics commercial high-level measure of transfer problem solving ability in science, for Pretest x Gender, F = .10 with p = .91 at 2, 51 df.

Table 4-18

3 x 2 (Treatment x Gender) ANCOVA for Genetics High-level Commercial Transfer Problem Solving Posttest

Source	df	SS	F	Pr>F
Pre	1	198.3920	29.10	0.0001*
Trt	2	4.7614	0.35	0.7068
Sex	1	46.8495	6.87	0.0113*
Trt*Sex	2	9.3072	0.68	0.5094

*p≤ .05

Table 4-19

3 x 2 (Treatment x Gender) ANCOVA for Genetics High-levelResearcher-Constructed Transfer Problem Solving Posttest

Source	df	SS	F	Pr>F
Pre	1	140.7170	25.80	0.0001*
Trt	2	8.6625	0.79	0.4570
Sex	1	20.9154	3.83	0.0552
Trt*Sex	2	25.1674	2.31	0.1089

*p≤ .05

Table 4-20

3 x 2 (Treatment x Gender) ANCOVA for Animal Behavior High-levle Commercial Transfer Problem Solving Posttest

Source	df	SS	F	Pr>F
Pre	1	20.5742	6.51	0.0134*
Trt	2	1.1144	0.18	0.8388
Sex	1	2.6236	0.83	0.3660
Trt*Sex	2	1.3380	0.21	0.8099

*$p \leq .05$

Table 4-21

3 x 2 (Treatment x Gender) ANCOVA for Animal Behavior High-level Researcher-Constructed Transfer Problem Solving Posttest

Source	df	SS	F	Pr>F
Pre	1	656.5020	19.78	0.0001*
Trt	2	110.6189	1.67	0.1977
Sex	1	17.0625	0.51	0.4762
Trt*Sex	2	257.8175	3.88	0.0260*

*$p \leq .05$

Table 4-22

3 x 2 (Treatment x Gender) ANCOVA for Solids, Liquids, and Gases High-level commercially-produced Transfer Problem Solving Posttest

Source	df	SS	F	Pr>F
Pre	1	0.0006	0.00	0.9814
Trt	2	5.2969	2.59	0.0839
Sex	1	0.1246	0.12	0.7282
Trt*Sex	2	3.8623	1.89	0.1606

*$p \leq .05$

Table 4-23

3 x 2 (Treatment x Gender) ANCOVA for Solids, Liquids, and gases high-level Researcher-Constructed Transfer Problem Solving Posttest (Winebottle)

Source	df	SS	F	Pr>F
Pre	1	2.0851	1.45	0.2338
Trt	2	1.2363	0.43	0.6528
Sex	1	1.3235	0.92	0.3416
Trt*Sex	2	5.1047	1.77	0.1791

*$p \leq .05$

Table 4-24

3 x 2 (Treatment x Gender) ANCOVA for Solids, Liquids, and Gases high-Level Researcher-Constructed transfer Problem solving Posttest (Bell Jar)

Source	df	SS	F	Pr>F
Pre	1	0.4823	0.27	0.6065
Trt	2	1.5059	0.42	0.6598
Sex	1	0.0725	0.04	0.8415
Trt*Sex	2	1.3102	0.36	0.6926

*$p \leq .05$

Table 4-25

3 x 2 (Treatment x Gender) ANCOVA for Solids, Liquids, and Gases total Battery of High-level Commercial and Researcher-Constructed Transfer Problem Solving Posttests

Source	df	SS	F	Pr>F
Pre	1	1.0361	0.19	0.6654
Trt	2	3.1008	0.28	0.7546
Sex	1	4.6562	0.85	0.3606
Trt*Sex	2	19.8992	1.82	0.1724

*$p \leq .05$

Table 4-26

3 x 2 (Treatment x Gender) ANCOVA for Atomic Structure high-Level Commercial transfer Problem Solving Posttest

Source	df	SS	F	Pr>F
Pre	1	452.5182	7.40	0.0088*
Trt	2	209.7637	1.71	0.1897
Sex	1	286.8665	4.69	0.0348*
Trt*Sex	2	229.0091	1.87	0.1636

*$p \leq .05$

For Pretest x Gender, F = .67 with p = .42 at 1, 51 df. From the Genetics researcher-constructed high-level measure of transfer problem solving ability in science, for Pretest x Treatment, F = .96 with p = .39 at 2, 51 df. For Pretest x Gender, F = .02 with p = .88 at 1, 51 df. From the Animal Behavior commercial transfer problem solving measure, for Pretest x Treatment, F = 2.79 with p = .07 at 2, 54 df. For Pretest x Gender, F = .55 with p = .46 at 1, 54 df. From the Animal Behavior researcher-constructed Video transfer problem solving measure, for Pretest x Treatment, F = .65 with p = .52 at 2, 54 df. For Pretest x Gender, F = .08 with p = .78 at 1, 54 df. From the Solids, Liquids, and Gases commercial transfer problem solving measure, for Pretest x Treatment, F = .04 with p = .96 at 2, 50 df. For Pretest x Gender, F = .13 with p = .72 at 1, 50 df. From the Solids, Liquids, and Gases researcher-constructed

Winebottle transfer problem solving measure, for Pretest x Treatment, F = .38 with p = .69 at 2, 50 df. For Pretest x Gender, F = .53 with p = .47 at 1, 50 df. From the Solids, Liquids, and Gases researcher-constructed Bell Jar transfer problem solving measure, for Pretest x Treatment, F = .77 with p = .47 at 2, 51 df. For Pretest x Gender, F = .97 with p = .33 at 1, 51 df. From the Solids, Liquids, and Gases total battery of transfer problem solving posttests, for Pretest x Treatment, F = .80 with p = .46 at 2, 49 df. For Pretest x Gender, F = .02 with p = .89 at 1, 49 df. From the Atomic Structure commercial transfer problem solving posttest, for Pretest x Treatment, F = .33 with p = .72 at 2, 49 df. For Pretest x Gender, F = .08 with p = .77 at 1, 49 df.

Analyses of Attitudinal Meaures

At the completion of the second 3-week unit of study, a measure of attitudes toward concept mapping (14 items) and/or a measure of attitudes toward cooperative learning (16 items) were administered to all students. Depending upon their respective treatment placement, students had experienced either one or both of these strategies.

To examine the effects of cooperative learning and concept mapping on attitudes toward each of these respective strategies, independent samples t-tests were conducted. Items from each of the attitudinal instruments were categorized into "thinking" or "feeling" subsections and these categories were compared for groups exposed to one of these two learning strategies with groups exposed to both strategies.

To protect the experiment-wise Type I error rate of .05, a Bonferroni adjustment was made resulting in a .025 nominal alpha level for each individual test. None of the findings were statistically significant. For the cooperative "feeling" attitude subsection, t (83) = -.0810, p = .94.

For the cooperative "thinking" attitude subsection, t (83) = -1.6297, p = .11. For the concept mapping "feeling" attitude subsection, t (79) = -.4624, p = .65. For the concept mapping "thinking" attitude subsection, t (79) = .8157, p = .42 (See Tables 4-27 and 4-28).

Table 4-27

Means (and Standard Deviations) for the "Thinking" and "Feeling" Subsections of the Cooperative Learning Attitudinal Measure

Treatment	n	"Thinking"	"Feeling"
Coop Only	43	28.740 (4.175)	22,070 (3.074)
Coop and Map	42	30.048 (3.107)	22.119 (2.501)

Table 4-28

Means (and Standard Deviations) for the "Thinking" and "Feeling" Subsections of the Concept Mapping Attitudinal Measure

Treatment	n	"Thinking"	"Feeling"
Map Only	39	26.692 (3.349)	21.359 (2.422)
Map and Coop	42	26.095 (3.237)	21.595 (2.176)

The results of the ANCOVAs conducted for the low-level measures of science achievement did not indicate that students constructing concept maps in cooperative groups perform better on these measures than students constructing concept maps independently or students working cooperatively without mapping. However, these analyses did demonstrate that, in this study, males performed significantly better than females on Genetics measures of low-level science content, independent of the treatment.

When conducting an ANCOVA for the Animal Behavior low-level measure of science content, the assumption of homogeneity of slopes was violated due to a significant three-way interaction (Pretest x Treatment x Gender) (Table 4-6). This treatment effect is represented in Appendix M. In general, the nature of the interaction indicates that the mapping only treatment was slightly better for the female students on this material (A and B). When the cooperative learning treatment is observed (C and D), it appears that overall performance by males was better than that for females. In particular, males who scored low on the pretest did much better than females who also had low pretest scores. Male and female students who were in the cooperative/mapping group performed equally well (E and F).

The results of the ANCOVAs conducted for the high-level measures of transfer problem solving ability in science did not indicate any benefits for students constructing concept maps cooperatively when compared with students constructing maps independently or students working cooperatively without mapping. A variety of effects of gender, however, were also significant for these measures of higher-level learning. Once again, males performed significantly better than females on a commercially-produced Genetics measure. This higher level section included the interpretation of Punnett Square grids. Scores on the researcher-constructed Genetics measure of transfer problem solving (nuclear), however, were not significant. The ANCOVA conducted for the researcher-constructed video measure indicated that males working cooperatively performed better on this transfer problem solving measure than males constructing concept maps in cooperative learning groups. Finally, in the case of the transfer problem solving measure for the Atomic Structure Unit, females outperformed males on this higher-level instrument. The analyses of the attitudinal measures administered in this study implied that neither participation in concept mapping nor participation in cooperative learning activities had significant effects on student attitudes toward these strategies.

Analyses of Scores From Concept Mapping Evaluation Procedure

It was hypothesized that students constructing concept maps in cooperative learning groups would be more likely to experience success with map construction than students constructing maps independently as a result of the cooperative elements of academic support, verbal interaction, and positive interdependence. Although results of the cognitive measures administered in this study did not reveal any statistical proof that mappers can learn academic material more meaningfully than non-mappers, Novak and Gowin (1984) maintain that concept map construction requires meaningful thought. If this is true, information regarding more efficient and successful methods of map construction would be beneficial. It was decided that comparing concept maps constructed independently with concept maps constructed cooperatively could provide pertinent information with respect to successful map construction.

Concept maps were scored using the concept mapping evaluation procedure established for this study (See Appendix J). All completed concept maps began this procedure with 85 points, and points were either added to or subtracted from this initial score on the basis of positive or negative performance with regard to mapping components. Project staff discussed and practiced these evaluation techniques together with sample maps and then scored the maps independently that were constructed for this study.

Direct comparisons between concept mapping scores was difficult due to the fact that the three treatment groups differed with respect to the number of concept maps produced. From groups mapping independently, approximately 20 maps were available for data analyses. Groups constructing concept maps in cooperative learning groups provided approximately seven maps for observation. Students completing packets of information cooperatively did not construct maps.

In spite of the different numbers of maps per treatment, however, project staff suggested that maps could be compared by relating them to a common index. Following this assumption, the components dealing with mapping flow, number of errors, relative ordering of concepts, number of cross-links, and examples of creative display of knowledge were graphed by frequency of occurrence on proportionate axes (See Figures 4-1, 4-3, 4-5, and 4-7). Mapping scores were also converted to percents and plotted for observation (See Figures 4-2, 4-4, 4-6, and 4-8).

Analyses of concept maps constructed for the Genetics Unit (Figure 4-1) show that six of the eight cooperatively constructed maps received credit for hierarchical flow of thought, while only eight of the 20 independent maps succeeded in that category. Regarding errors in construction, where conceptual placements or relationships were inaccurate, six of the eight cooperative maps were without errors as compared to only seven of the 20 independent maps. The proportions of cross-link formation and examples of creative use of knowledge were also greater for maps constructed in cooperative learning groups.

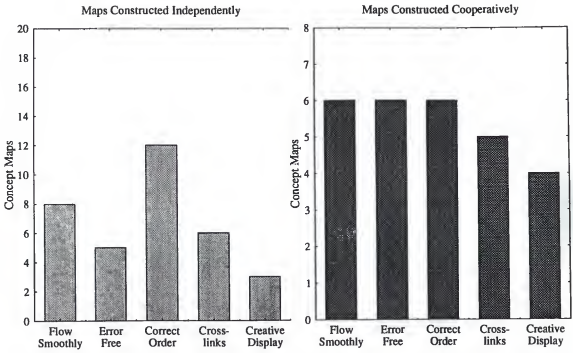


Figure 4-1. A comparison of the frequency of essential concept mapping elements for the Genetics Unit.

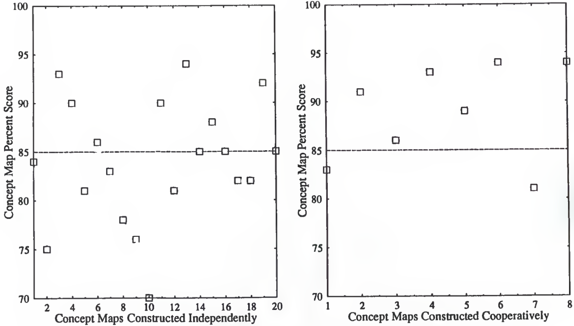


Figure 4-2. A comparison of concept map scores for the Genetics Unit using the evaluation procedure described in this study. A reference line is drawn at the 85% mark to facilitate visual comparisons.

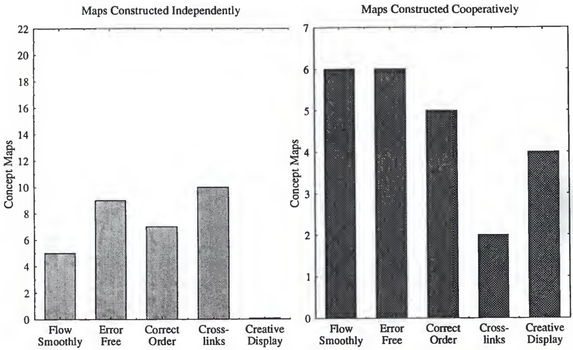


Figure 4-3. A comparison of the frequency of essential concept mapping elements for the Animal Behavior Unit.

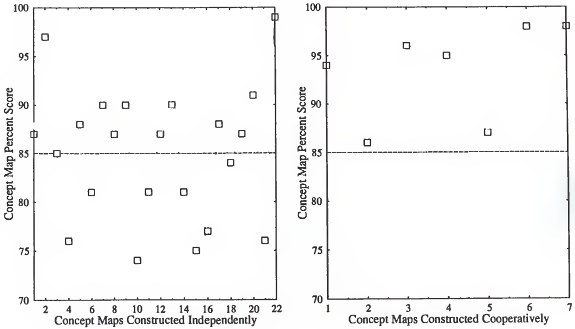


Figure 4-4. A comparison of concept map scores for the Animal Behavior Unit using the evaluation procedure described in this study. A reference line is drawn at the 85% mark to facilitate visual comparisons.

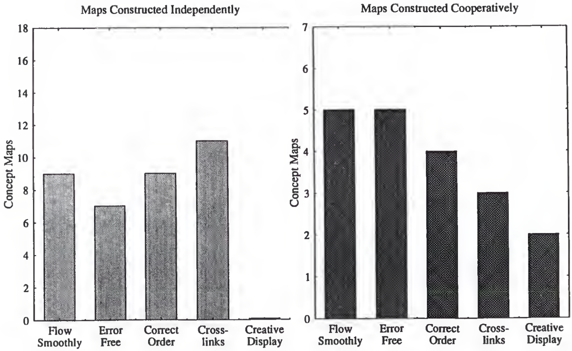


Figure 4-5. A comparison of the frequency of essential concept mapping elements for the Atomic Structure Unit.

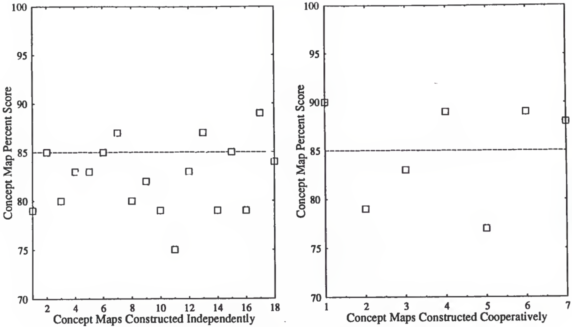


Figure 4-6. A comparison of concept map scores for the Atomic Structure Unit using the evaluation procedure described in this study. A reference line is drawn at the 85% mark to facilitate visual comparisons.

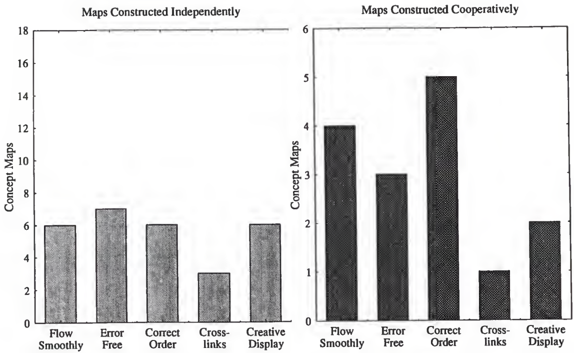


Figure 4-7. A comparison of the frequency of essential concept mapping elements for the Solids, Liquids and Gases Unit.

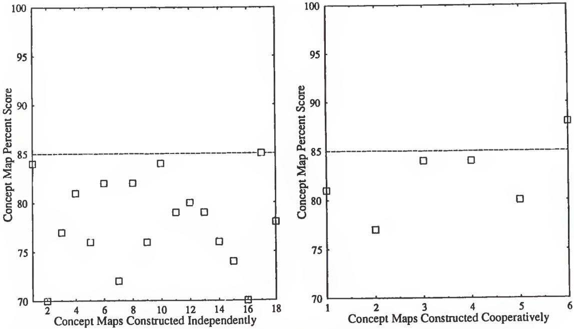


Figure 4-8. A comparison of concept map scores for the Solids, Liquids, and Gases Unit using the evaluation procedure described in this study. A reference line is drawn at the 85% mark to facilitate visual comparisons.

A comparison of concept maps constructed for the Animal Behavior Unit (Figure 4-3) shows patterns similar to those found for the Genetics Unit with the exception of the frequency of mapping cross-links. In this case, independent mappers outscored cooperative mappers. Almost half of the maps constructed independently contained at least one cross-link compared to less than one-third of cooperatively constructed maps. However, in the category of creative displays of knowledge, more than half of the cooperative maps contained one example, compared to none for the independent group.

As with the Animal Behavior and Genetics Units, cooperatively constructed maps from the unit on Atomic Structure (Figure 4-5) had a slightly higher proportion of essential concept mapping components than independently constructed maps, with the exception of the formation of cross-links. Creative displays of knowledge were low overall, with independent maps given no credit in this category.

As with previously reviewed units, cooperatively generated maps for the Solids, Liquids, and Gases Unit (Figure 4-7) were more likely to be clearly understood by the reader. They were more likely to be free from errors in content and accurately demonstrate conceptual ordering. The numbers of cross-links and creative displays of knowledge were approximately the same for both groups.

Comparisons of mapping scores for the Genetics Unit (Figure 4-2) and Animal Behavior Unit (Figure 4-4) indicated that maps constructed cooperatively had a better chance of successfully meeting mapping criteria than maps constructed independently. Mapping scores calculated from the Solids, Liquids, and Gases Unit were lower overall than maps from the other units, with the lowest scores given to maps constructed independently. The map scores for the unit on Atomic Structure seemed to show fewer differences between maps constructed cooperatively and maps constructed independently.

A review of other data accumulated from the concept mapping evaluation checklist reveals some interesting information with regard to procedural mapping elements. For the Genetics Unit, the eight maps constructed cooperatively lost no points for overall neatness, unconnected concepts, or unlabelled propositions. On the other hand, of the maps constructed independently, approximately 25% lost points in all of these categories.

Only one unlabelled proposition and no unconnected concepts were found in observations of the cooperatively constructed concept maps for the unit on Animal Behavior, wheras almost half of all maps constructed independently lost points in these categories. Similar tendencies were noted for the units on Atomic Structure and Solids, Liquids, and Gases, although not as dramatically different. However, with regard to unlabelled propositions for the unit on Solids, Liquids, and Gases, 14 of the 18 independently constructed maps lost points in this category compared to two of the six cooperative maps.

When compared to a similar index, it appears that concept maps constructed cooperatively are less likely to have unconnected concepts or unlabelled propositions. They are less likely to contain errors, have concepts out of an accepted hierarchical order, or lack logical conceptual connections. When read through for facility of flow, maps constructed cooperatively were easier to follow, suggesting a better overall understanding of unit concepts. Comparisons of map scores indicate that in many cases maps constructed cooperatively are better constructed than maps provided by individuals.

There are few indications of low scores given to cooperative maps. Students working cooperatively were successful in producing a quality product which ideally contained input from all group members. Individual mappers did not experience the cooperative "pressure" of positive interdependence. This may partially explain the fact that most low scores were from maps constructed individually. Although maps were not assigned as homework, independent mappers were more likely to work on maps at home. Group mappers seemed to do all of their actual mapping within the confines of the classroom environment, working cooperatively with their peers. Responsible only to themselves, independent mappers could have been more likely to formulate and develop incorrect ideas.

Although most high scores were awarded to maps constructed cooperatively, there were many independently constructed maps that received high scores without group input or pressure. The individuals who constructed them may have, in fact, preferred the freedom of going in their own mapping direction without having to negotiate a consensus decision.

There are no clear patterns indicated for construction of cross-links or examples of creative expression of knowledge. Cross-links are given a high priority by Novak & Gowin (1984) as being examples of interrelating large chunks of knowledge. One could argue that a cooperative group could stimulate creative thought by positive interaction or stifle individual thought through peer pressure.

CHAPTER V
DISCUSSION

The first part of this Chapter gives a description of the step-by-step "guided" mapping procedure used in this study that is credited with successful concept map construction by 7th and 8th graders. Following this is a discussion of factors that could affect the degree of controversy for a topic. Segments of concept maps that illustrate creative displays of conceptual relationships are shown, and the Chapter closes with a discussion of some of the methodological and procedural limitations that could have affected the results of this study and suggestions for future research.

Successful Mapping

Most 7th and 8th graders in the mapping groups achieved the staff's criteria for successful mapping. Constructed maps consisted of a minimum of 25 terms, hierarchically organized, and connected in propositional statements. Students who constructed the maps and staff members could read through completed maps from top to bottom. Many student maps included more than the minimum number of concepts required and one or more cross-links.

Based upon other mapping studies (Lehman et al., 1985; Novak et al., 1983), the high degree of success for these 7th and 8th graders seems impressive, especially considering their relatively short introduction to concept mapping (approximately one week), and the fact that few if any of these students had ever been exposed to mapping exercises before. This is not to say that these students achieved a high level of proficiency in concept map construction, only that their initial experiences were successful and therefore positive. The steps taken to ensure mapping success for these students are considered a strength of this study.

The procedural sequence for concept map construction used here was based upon recommendations by Novak (1980), Novak and Gowin (1984), and Novak et al., (1983). The modifications introduced were largely with regard to the formation of the hierarchy of terms for the academic units to be learned and will be discussed at the appropriate place in the following explanation of procedures.

All students in all treatments were first exposed to a series of "Learning to Learn" activities designed to illustrate the relationships between sensory, short term, and long term memory, and the nature of concepts and meaningful learning (Novak, 1980). Students in groups that would be mapping were given examples of simple hierarchical structures using concepts that they were already familiar with and then asked to construct a hierarchy of their own choice using a list of teacher-selected concepts. They were guided to discover that a variety of hierarchical possibilities can exist for a group of concepts depending upon an individual's unique set of perspectives (See Figure 5-1). Step-by-step teacher instruction was then used to demonstrate how this hierarchy could be expanded into a concept map or two-dimensional representation of a particular segment of knowledge (See Figure 5-2). As the study progressed, these students were asked to follow these same procedures with selected concepts from the information in each chapter.

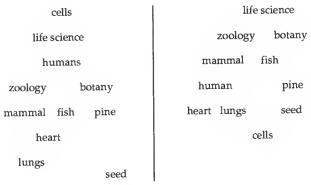


Figure 5-1. Two equally valid student-constructed hierarchies.

The following modifications have not been described in the literature and are considered an important factor for student success with mapping in this study. The approximately 15 or so unit concepts that were selected by the teacher for the initial hierarchy were typed out for the student along with a clear, concise definition of each term. Each concept and its appropriate definition were enclosed in a rectangular box. Students were assigned the task of learning these 15 terms and their definitions for a quiz the following day. They were also asked to cut out the rectangular pieces of paper, with

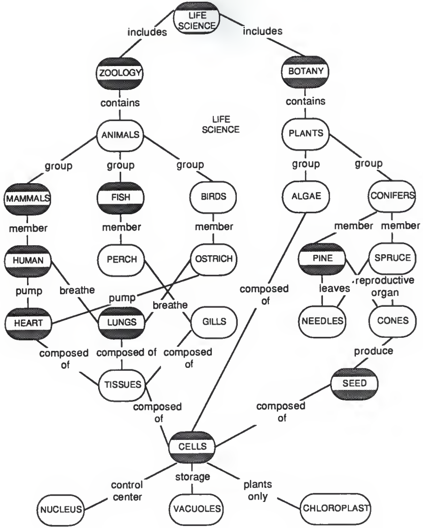


FIGURE 5-2. Concept map constructed from hierarchical terms. Original terms are shaded in.

both the concept name and its definition, and arrange them into a hierarchy as they had been instructed in the introductory example. They were again reminded to work downward from the most general ideas at the top and to look for terms that they considered of equal "weight" to line up horizontally.

When students were satisfied with the organization of their hierarchy, they were required to glue the rectangular pieces onto a separate sheet of paper and record their reasons for conceptual placement at each level (See Figure 5-3). These hierarchical lists were handed in to the teacher and checked over for incorrect placements or inaccurate reasoning. In many first submissions, the terms that were not clearly understood were often shuffled down to the bottom of the list. In one case, a group of students placed all of the concepts horizontally claiming that they were all equally important. Corrected and approved hierarchies were then returned to the students for the addition and assimilation of 10 or more additional conceptual terms and final concept map construction. It should be noted that the hierarchies returned to students almost always underwent major revisions before final maps were constructed (See Figure 5-4).

Having students take a quiz on the initial 15 terms and give reasons for their conceptual placements in the hierarchy was something that the project staff regarded as imperative for mapping success. It became evident very early in this study that students could not form a hierarchy and therefore could not construct a successful concept map until they had reached a certain level of understanding for these terms. Without this "knowledge

Conceptual Placement			Reasons for Conceptual Placement
genetics			The study of all the knowledge that is to follow
heredity			The term used to describe the passing along of characteristics
nucleus			The place where the genetic material is located
sex chromosomes	chromosomes	DNA	The "packages" of the genetic material
sex-linked traits	genes	traits	Contained in the genetic packages
dominant	recessive		Traits can be strong or weak
pure	hybrid		Traits can be the same or mixed
incomplete dominance			When both traits show up

Figure 5-3. Student-constructed hierarchical list for the Genetics Unit with reasons for placement.

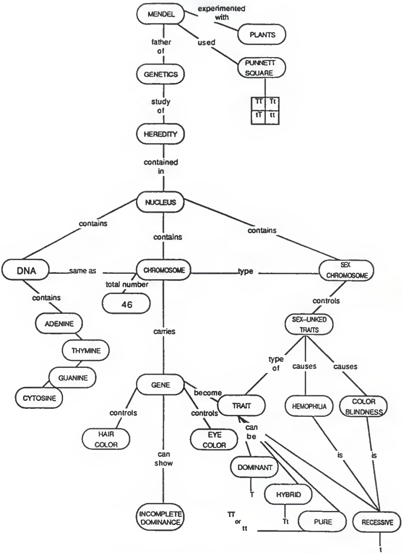


Figure 5-4. A concept map constructed by a student working independently.

readiness level," students could not compare one term with another and evaluate their relative importance. Lacking this necessary prerequisite, they could not establish a hierarchy. The additional steps of incorporating more concepts and constructing accurate propositions were facilitated by this "guided" mapping approach.

Insufficient Basis for Controversy

One goal of this study was to introduce an element of academic controversy into the cooperative learning groups. Research has shown that both academic and social growth for students working cooperatively have been greatest in an atmosphere of constructive controversy (Johnson & Johnson, 1989). While provisions were made in this study to implement collaborative skills that nurture positive academic controversy, such as listening carefully, encouraging everyone to participate, criticizing constructively, and separating the academic issue from an individual's opinion, more thought could have gone into how topic selection and background information influence the level or opportunity for controversy.

Academic controversies structured by Johnson and Johnson (1985) included topics selected for their controversial value from which two, well-documented, alternative position statements could be prepared. Groups of four students were divided into pairs. Each pair was then assigned a pro or con position and asked to learn prepared background information supporting this view. They presented their position, exchanged materials and presented the alternative argument, and then met as a group of four to discuss the information and prepare a consensus summary.

Similar collaborative skills were stressed in this study. However, the information for which the students were responsible was not presented in a controversial context or always well-suited for that purpose. Students were encouraged to challenge conceptual placements on concept maps or answers to items in their group packet if they did not agree. They were encouraged to have carefully considered reasons for disagreeing and to maintain their position unless logically persuaded to accept another point of view.

There is no question that certain topics are more suitable for structuring academic controversies than others. In general, it could probably be assumed that the 7th grade units on Genetics and Animal Behavior provided more opportunities for student discussion at this level than the 8th grade units on Solids, Liquids, and Gases and Atomic Structure. Presenting students with a scenario about a nuclear power plant disaster and possible genetic damage could stimulate more student interest and dialogue than a topic on atomic structure in which background information was limited and conceptual applications were more difficult to conceive.

According to Johnson and Johnson (1989), controversy exists when one person's ideas or information are incompatible with those of another and an attempt is made to reach an agreement. To debate an issue, an individual needs sufficient background information about the subject before feeling confident about expressing him/herself and initiating a controversial situation. In many cases in this study, provided background information was probably not extensive enough to instill the confidence necessary for challenging another's point of view. In these cases, students working cooperatively could have been more willing to agree with peers perceived as high academic achievers in spite of teacher prodding to challenge questionable answers.

Creative Representations of Conceptual Ideas

Many of the constructed concept maps provided creative representations of key concepts. Novak and Gowin (1984) have claimed that concept maps provide an opportunity for the creative expression of knowledge and sections of many maps constructed in this study demonstrate that feature. Figure 5-5 shows a segment of a map constructed for the Genetics Unit. It visually represents that the message inscribed on the DNA molecule is carried out of the nucleus by RNA to the ribosomes where appropriate protein synthesis occurs. In this case, the student has placed DNA at a higher hierarchical level than the term nucleus suggesting that the genetic material is considered more important than its location within the nucleus of the cell. In Figure 5-6, the student has chosen to place the term nucleus above DNA in the hierarchy because he considered the site where the genetic material is located as more inclusive than the materials within the nucleus. The student's mapped representation of the structure of a DNA molecule shows a good understanding of its basic structure.

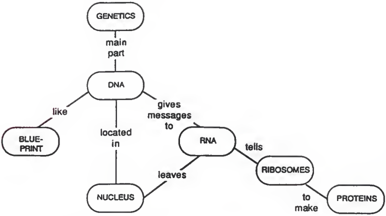


Figure 5-5. A section of a concept map from the Genetics Unit illustrating the steps in protein synthesis.

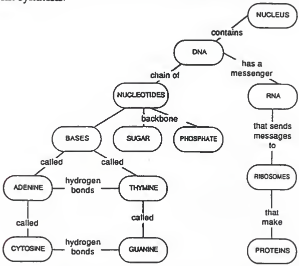


Figure 5-6. A section of a concept map from the Genetics Unit illustrating an understanding of the basic structure of a DNA molecule.

Figure 5-7 is a section of a map from the unit on Solids, Liquids, and Gases. This student added arrows to her concept map to give direction to the propositional statements. The concepts solid, liquid, and gas are shaded in because they had been highlighted on the original map. It is interesting to note that she positioned concepts associated with heat gain above the terms solid, liquid, and gas while terms associated with a loss of heat are below.

Figures 5-8 and 5-9 demonstrate other ways that concept maps can effectively display knowledge in two dimensions. Figure 5-8 represents how a group of students visualized the structure and function of the human ear in a concept map drawn for the unit on Animal Behavior, and Figure 5-9 represents a view of social organization and behavior from the same unit. Finally, Figure 5-10 shows a student response to the Winebottle question from one of the 8th graders involved in this study in which he used a concept map to help answer the question without being prompted to do so.

Factors Affecting the Results

Students constructing concept maps in cooperative learning groups did not perform any better on quantitative measures of science achievement or attitudes toward the instructional experience than students mapping independently or students working cooperatively without mapping. The factors that could explain this lack of quantitative support for using both learning strategies together can be grouped into methodological and procedural limitations of the study.

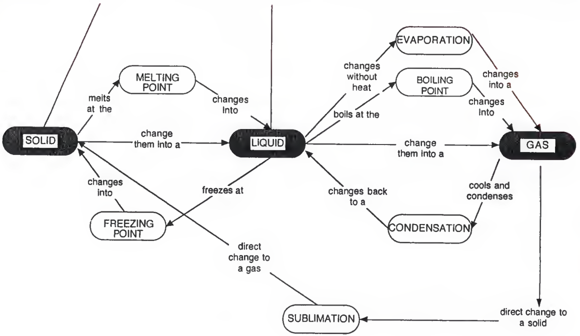


Figure 5-7. A section from a concept map from the Solids, Liquids, and Gases unit illustrating relationships among the 3 states of matter. The shaded areas represent spaces that were highlighted by the student.

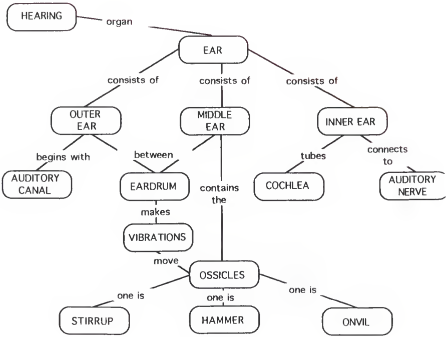


Figure 5-8. A segment of a concept map from the unit on Animal Behavior representing the structure of a human ear.

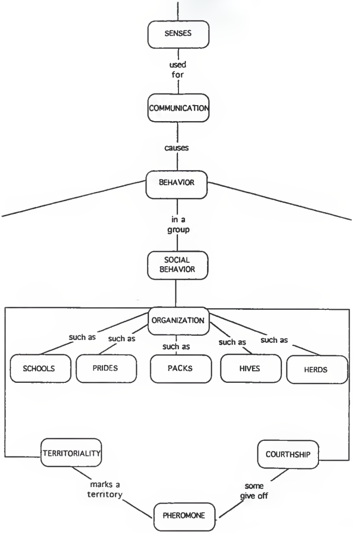
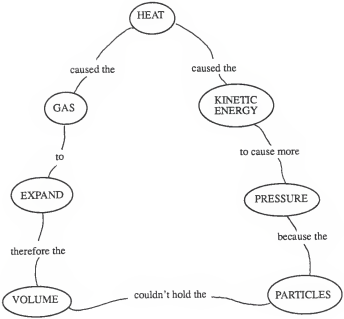


Figure 5-9. A segment of a concept map from the unit on Animal Behavior representing some aspects of social organization and behavior.



The temperature in the refrigerator caused the particles to slow down a lot. Then the heat caused the kinetic energy to expand, therefore making the pressure in the glass more than the volume could hold. The gas forced the cork out of the bottle.

Figure 5-10. A student-constructed response to the Winebottle problem.

Methodological limitations of the study include (a) the confounding of teacher and grade level, (b) problems with the unit of analysis, (c) suitability of the measures of the dependent variables, (d) the lack of a no-treatment control, (e) unique treatment strengths and weaknesses, (f) the power of cooperative learning, and (g) the large number of novel ideas incorporated into this short-term study.

Procedural limitations of this study include (a) insufficient time for the concept mapping or cooperative learning effects to emerge, (b) lack of equivalence among groups in time-on-task, and (c) the Hawthorne Effect.

Methodological Limitations of the Study

Confounding of teacher and grade-level. In this study, there was only one teacher per grade level. Concern over this confounding of teacher and grade level was increased because the researcher was the teacher at the 7th grade level. Rigorous efforts were made to reduce concerns over this effect: (a) implementation of strict guidelines and specific instructions for both classroom teachers regarding organization, timing, implementation, and evaluation of cooperative learning and concept mapping procedures; (b) scheduling of daily team meetings and reciprocal observations by the researcher and the other participating teacher to assure consistency with regard to all in-progress procedures; (c) establishing a uniform system for administering and evaluating the dependent variables, and (d) arranging for daily monitoring of classroom procedures by members of the support group who were familiar with the basic hypotheses of the study.

Problems with the unit of analysis. The unit of analysis for this study was the non-randomly selected individual student. It would have been better to have multiple class sections per treatment and treat each section as the unit of analysis, rather than the individual child. When a treatment is administered at class level and data are collected at student level, there is always a possibility that there is some violation of the assumption of independence of observations required for ANCOVA.

More appropriate dependent variables. Pre-and posttests could have better matched the variables of interest in each dimension. In addition to tests of specific content, measures designed to evaluate concept development, mapping capabilities, content mastery, elaboration of a topic, hierarchical formation of terms, decision-making, and peer cooperation would have been appropriate. However, because not all treatment groups constructed concept maps, and not all treatment groups worked cooperatively, results from these types of measures would be difficult to compare. For these reasons, the major foci of interest were mastery of content and general problem solving capability.

Lack of a no-treatment control. The fact that there were only three classes per grade level at the study school and three treatments administered did not allow for a fourth, no-treatment, control group to be included in the study and observed. Comparisons with a no-treatment control group could have given this researcher a better indication of treatment effects.

Strengths and weaknesses of treatment: Independent mappers. Students constructing concept maps independently were not allowed to engage in any more student-student interaction than that demonstrated in a traditional setting. They did not benefit from the peer support, peer feedback, academic conflict, or elaboration experienced by students working cooperatively. However, as a result of this lack of peer interaction, these individuals sought and required far more teacher assistance and teacher contact time than students working cooperatively. This increased, one-to-one, student-teacher interaction may have benefitted students in this group who received this "expert" input, and partly filled the gap or need for a "sounding board" that these individuals needed.

Strengths and weaknesses of treatment: Cooperative non-mappers. Students working cooperatively without concept mapping completed a packet of worksheets, puzzles, and other review and reinforcement materials that accompanied the Merrill textbooks. Although they engaged in and benefitted from a good deal of student-student interaction while discussing answers to packet items, they did not have the same opportunity for constructive controversy that cooperatively grouped mappers did. The commercially produced supplementary materials that constituted the packet did not provide the stimuli for academic controversy evident in the two-dimensional, visual representation of knowledge provided by a concept map. Students not mapping were not likely to consider hierarchical order, conceptual priorities, or interrelationships to the degree that mappers did and were not exposed to the mental manipulation of concepts that the elements of subsumption, progressive differentiation, and integrative reconciliation require. However, it is possible that this treatment group had an advantage over the other groups with respect to the similarity of packet materials to test format. Project staff reviewing the packets of review and reinforcement materials and the corresponding achievement tests noted many similarities in format, theme, and content. These similarities may have positively affected test scores.

The power of cooperative learning. The classroom teachers involved in this study were familiar with the basic elements of cooperative learning and conscientiously applied these elements to every aspect of student group work. The targeted collaborative skills were identified and discussed using T-Charts, stressed as imperative for learning success, observed for using observation checklists, and linked to accumulation of bonus points. In addition to rigorous monitoring procedures, processing time was provided so students could discuss how well they were doing and where improvements were needed.

Results of cooperative learning research (Johnson & Johnson, 1989) support the possibility that gains in achievement for conceptual and problem solving tasks could be attributed to the implementation of cooperative learning on its own merits. Johnson and Johnson (1985) have linked discussions in cooperative learning groups with transfer problem solving and meaningful learning and with positive attitudes toward the instructional experiences. The social interdependence of a cooperative learning group could have a greater impact on academic success than a two-dimensional concept map. The cooperative element of formative evaluation could have also affected both concept map success and cognitive test results for all treatments as the teachers in this study frequently assessed levels of performance to uncover knowledge gaps.

The novelty effect. Mention also should be made of the large number of new practices and procedures introduced to students in this study. Concept mapping was new to most or all 7th and 8th graders. Most students were also unfamiliar with cooperative learning experiences that emphasize positive interdependence, face-to-face interaction, individual accountability, teacher monitoring and processing, and the development of collaborative skills. The assignment of a student facilitator (Cohen, 1986) to each cooperative learning group was another task most students had never experienced.

Procedural Limitations of the Study

Hawthorne effect. A Hawthorne effect should not be ruled out concerning the performance of all groups in this study. Both students and faculty were interested in the topics of study and the new methods being used in teaching, and it is possible that many individuals performed at higher levels than usual on this material.

Insufficient time. According to Novak (1990), many studies investigating the use of instructional strategies like concept mapping and its effect upon meaningful learning have demonstrated a pattern that could influence data interpretation for short-term studies. Students new to the concept mapping heuristic have tended to show a decrease in performance on standardized course exams during the first 2 to 4 weeks before demonstrating increases that become significant over time (Moreira, 1977). A shift in attitude was also observed over time from negative to positive toward both the concept mapping strategy and the course content.

Lack of equivalence in time-on-task. Project staff observed that students constructing concept maps in cooperative learning groups engaged in stimulating discussions regarding map organization and required minimal teacher assistance for map completion. Students constructing concept maps independently generally required, and were allowed, an additional class period and more teacher assistance to complete their maps.

Suggestions for Further Research

Because of the numerous methodological and procedural limitations that influenced the results of this study, it is recommended that these same hypotheses be tested on a larger scale using the limitations noted in this Chapter as recommendations for improvement.

The number of teachers and class sections could be increased to provide multiple class sections per treatment and allow each section to be treated as a unit of analysis. The study should continue over a longer period of time to allow development of the positive effects of concept mapping and cooperative learning. Research has shown that both concept mapping skills and collaborative skills improve with time (Johnson & Johnson, 1989; Novak & Gowin, 1984). If this study could be implemented at the beginning of a school year, the task of the facilitator would be less difficult. In this study, facilitators were assigned to self-contained groups of students in the middle of the year and academic and social roles had already been well established. Even in this relatively short-term study, however, the project staff observed excellent efforts by the facilitators to encourage participation by all group members.

It would be interesting to see the researcher-constructed transfer problem solving measures developed for this study used again in a larger study to investigate their use for evaluating meaningful learning. The Winebottle Test, bell jar demonstration, Genetics nuclear measure, and Animal Behavior video measure could probably be used unchanged, unless the study population and unit content required modifications.

It would also be interesting to see how the concept mapping evaluation procedure used in this study would apply to concept maps constructed in other studies. Would this evaluation system function effectively in another setting and with other evaluators? Would maps constructed by students working cooperatively take less time to complete and be more "successfully" completed than those constructed by students working independently? Teachers who have found concept mapping construction particularly difficult and time-consuming would be interested in research demonstrating that concept map construction in a cooperative group takes less teacher time and effort.

The concept maps produced by students in this study were constructed either individually or cooperatively. In both cases, the completed maps were handed in and graded and then returned to students with little follow-up. Other studies could investigate more productive uses for the finished maps. Students could make transparencies of the completed maps and present them to the class for discussion. They could be allowed to use their maps during a test which would provide an incentive for making maps as thorough and accurate as possible.

Finally, the gender effects that occurred in this study could be a stimulus for a wide-range of related studies investigating the many facets of cooperative learning and concept mapping. Very little cooperative learning research dealing with gender issues has been conducted which is surprising considering its heterogeneous group requirement. The findings of Conwell and others (1993) that show a relationship between group composition and academic achievement for females emphasizes the importance of student placement in groups. This placement may have more of an effect on female achievement than treatment.

No studies dealing with gender issues and concept mapping have been found in the literature by this researcher. How does mapping performance for females compare to that for males? Are there gender effects for meaningful learning? Are there differences in the ways that males and females arrange hierarchical terms or construct a concept map.

Do attitudes of males and females differ regarding constructive controversies or the importance of collaborative skills. Do males and females differ in their attitudes toward concept mapping. These gender issues should be explored as major hypotheses and not as peripheral issues.

Conclusion

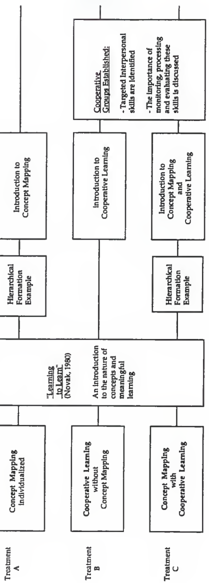
To construct a concept map, an individual needs a basic understanding of all the concepts or terms that are to be included. Without this "knowledge readiness level," the essential hierarchical component cannot be successully constructed. Middle and high school students have often encountered dificulties while attempting to construct concept maps (Lehman et al., 1985; Novak et al., 1983). With few exceptions, 7th and 8th grade students involved in this study were able to successfully construct a basic concept map for a unit of knowledge. The "guided" mapping procedure used in this study could help increase the likelihood of mapping success for middle school students.

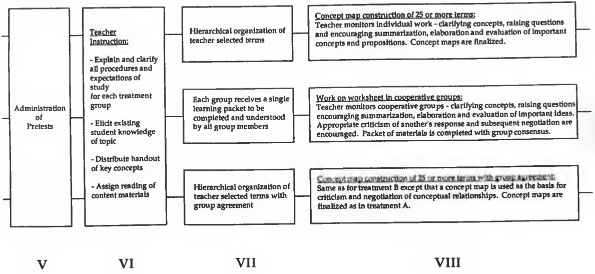
Constructing a concept map for a newly introduced unit of knowledge is a challenging and time-consuming task. Even with the guided approach used in this study, successful map construction took one full week after new content had been introduced. When constructed concept maps were compared by relation to a common index, there were indications that in many cases, but not all, concept maps constructed cooperatively took less time for completion and presented a better overall understanding of a unit of knowledge than maps constructed individually. Students working independently did not have the opportunity or benefit of positively interacting with their peers about mapping procedures or organization.

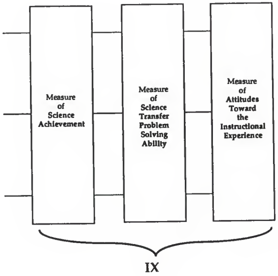
It may be that middle school students would have more overall success with concept mapping, and have a more positive attitude about its relationship to their own learning success, if they were allowed to map cooperatively. Adding the element of controversy as a collaborative skill would encourage them to look critically at each other's ideas, and concept mapping provides many opportunities for this process.

If students are encouraged to elaborate and defend their concept maps to other students or are allowed to use their maps on a written test to help organize their ideas, concept map construction could become a more practical tool for students. Once concept maps are successfully constructed by students, these individuals would be more likely to experience some of the benefits of mapping that Novak and Gowin (1984) discuss. Continued success with mapping could generate a positive attitude toward instructional experiences as students "learn how to learn" (Novak & Gowin, 1984). Students would begin to understand that conceptual meanings do not exist in isolation but in association with a large number of other concept meanings and selectively sift out relevant from irrelevant information.

APPENDIX A
RESEARCH STUDY FLOW CHART


Treatment A
Treatment B
Treatment C
Concept Mapping Individualized
Cooperative Learning without Concept Mapping
Concept Mapping with Cooperative Learning
"Learning to Learn" (Novak, 1980)
An introduction to the nature of concepts and meaningful learning
Hierarchical Formation Example
Hierarchical Formation Example
Introduction to Concept Mapping
Introduction to Cooperative Learning
Introduction to Concept Mapping and Cooperative Learning
Cooperative Groups Established:
- Targeted interpersonal skills are identified
- The importance of monitoring, processing and evaluating these skills is discussed
I
IIa
IIb
III
IV


Administration of Pretests
Teacher Instruction:
- Explain and clarify all procedures and expectations of study for each treatment group
- Elicit existing student knowledge of topic
- Distribute handout of key concepts
- Assign reading of content materials
Hierarchical organization of teacher selected terms
Each group receives a single learning packet to be completed and understood by all group members
Hierarchical organization of teacher selected terms with group agreement
Concept map construction of 25 or more terms: Teacher monitors individual work - clarifying concepts, raising questions and encouraging summarization, elaboration and evaluation of important concepts and propositions. Concept maps are finalized.
Work on worksheet in cooperative groups: Teacher monitors cooperative groups - clarifying concepts, raising questions encouraging summarization, elaboration and evaluation of important ideas. Appropriate criticism of another's response and subsequent negotiation are encouraged. Packet of materials is completed with group consensus.
Concept map construction of 25 or more terms with group agreement: Same as for treatment B except that a concept map is used as the basis for criticism and negotiation of conceptual relationships. Concept maps are finalized as in treatment A.
V
VI
VII
VIII


Measure of Science Achievement
Measure of Science Transfer Problem Solving Ability
Measure of Attitudes Toward the Instructional Experience
IX

APPENDIX B
COOPERATIVE GROUP EXPECTATIONS

"Sink or Swim Together"
Be a Successful Group Member

1. All members are encouraged to contribute to discussion:
    a. face each other
    b. stay with group
    c. use quiet voices
2. Ask questions when you do not understand.
3. Check that all group members understand the information that is to be mastered and can explain it when called upon.
4. Listen carefully to each other.
5. Explain your ideas and encourage other group members to summarize or elaborate their ideas.
6. Don't agree unless logically persuaded to do so.
7. If you disagree with a group member, give specific reasons for your disagreement.
8. Attempt to criticize an idea without criticizing a person.

APPENDIX C

T-Chart: A technique suggested by Johnson, Johnson, & Holubec (1986) for discussing the use of collaborative skills. This chart has some ideas for the skill of encouraging.

Looks Like	Sounds Like
Student makes eye contact.	"Good idea!"
Student smiles.	"What's your idea?"
Student gives thumbs up.	"Awesome!"
Student gives a pat on the back.	"You can do it!"

APPENDIX D
TRANSFER PROBLEM SOLVING MEASURE FOR GENETICS UNIT

A large nuclear power plant has been damaged by an explosion and dangerous levels of radiation have been released into the atmosphere. Employees and local residents have been exposed to excessive amounts of radiation. Doctors performing medical examinations have determined that this excessive radiation has altered the structure of the DNA molecules in the body cells of exposed individuals.

List as many statements as you can to describe the possible consequences of such an event. In your responses, include the following terms as well as any additional information you feel is appropriate.

chromosome
DNA
gene
sex chromosomes
nucleus
RNA
protein
sex-linked
trait
dominant
pure
mutation
heredity
incomlete dominance
hybrid
recessive

APPENDIX E
TRANSFER PROBLEM SOLVING MEASURE FOR ANIMAL BEHAVIOR UNIT

Animals interact with their environments in many ways. Observe these segments from the video Life on Earth and attempt to explain the behaviors you observe. List as many accurate statements as you can below. Use the following terms as well as any others that you think are appropriate.

behavior
reflex
conditioning
communication
reasoning
sight
taste

stimulus
trial and error
territoriality
instinct
pheromone
touch
smell

response
inborn behavior
acquired behavior
social behavior
senses
hearing
courtship

1. ____

2. ____

3. ____

4. ____

5. ____

6. ____

7. ____

8. ____

9. ____

10. ____

APPENDIX F

TRANSFER PROBLEM SOLVING MEASURES FOR UNIT ON SOLIDS, LIQUIDS, AND GASES

1. Winebottle Test

An empty wine bottle is left in the refrigerator overnight. In the morning it is taken out. A cork is stuck in the mouth of the bottle and the bottle is left on the windowsill where the warm rays of the sun are allowed to hit it. Several minutes later the cork pops right out of the bottle.

In a series of short statements explain why the cork popped out of the bottle. Include the terms below in your answer. Take a few minutes to organize your thoughts before you begin writing your answer.

expansion
gas
heat
kinetic energy
particles
pressure
temperature
volume

2. Balloon Demonstration

List as many statements as you can that describe and explain the changes you observed. Include the terms below (use them as often as you need to).

particles
volume
pressure
temperature
mass
balloon
bell jar

APPENDIX G
TRANSFER PROBLEM SOLVING MEASURE FOR UNIT ON ATOMIC STRUCTURE

1. Silicon has two isotopes. ${}^{28}_{14}\mathrm{Si}$ makes up 70% of naturally-occuring silicon. ${}^{29}_{14}\mathrm{Si}$ makes up 30%.

   a. Draw a model of an atom of each isotope of silicon.

   b. Compare and contrast the atomic structure of the silicon isotopes.

   ____

   ____

   ____

   ____

   c. Calculate the average atomic mass of silicon.

APPENDIX H
MEASURE OF ATTITUDES TOWARD CONCEPT MAPPING

Please use the this evaluation to assess your experience with concept mapping. Circle the appropriate number:

1 - strongly disagree
2 - disagree
3 - neutral
4 - agree
5 - strongly agree

Thinking

1. Concept mapping helps me to understand the knowledge presented in a science unit. 1 2 3 4 5
2. I rely less on memorizing facts when I construct a concept map of the information. 1 2 3 4 5
3. Concept mapping confuses me more than it clarifies knowledge for me. 1 2 3 4 5
4. Connections in my mind are clearer after I put them on paper in a concept map. 1 2 3 4 5
5. Concept mapping helps me to understand how I learn. 1 2 3 4 5
6. After mapping, I have a better understanding about how all facts in a science unit are related. 1 2 3 4 5
7. Constructing a concept map helps me to remember the subject matter. 1 2 3 4 5

Feeling

8. The time involved in constructing a concept map is too long for what it is worth. 1 2 3 4 5
9. I feel frustrated when the concepts don't all fit together. 1 2 3 4 5
10. I feel confused when I start map-making. 1 2 3 4 5
11. I feel good when the map all comes together.
12. I feel successful when I make a good map. 1 2 3 4 5
13. I feel frustrated when the same concepts can be viewed in different ways. 1 2 3 4 5

Acting

14. Concept maps could help me understand information in other classes. 1 2 3 4 5

APPENDIX I
MEASURE OF ATTITUDES TOWARD COOPERATIVE LEARNING

Please use this evaluation to assess your experience with cooperative learning. Circle the appropriate number:

1 - strongly disagree
2 - disagree
3 - neutral
4 - agree
5 - strongly agree

Thinking

1.	I understand information better when I work with others in a cooperative group.	1	2	3	4	5
2.	I try harder knowing that other group members are depending on me.	1	2	3	4	5
3.	Listening to other ideas and points of view helps me understand.	1	2	3	4	5
4.	Cooperative group members learn more when differing points of view are challenged.	1	2	3	4	5
5.	The more I explain ideas to others, the more I learn.	1	2	3	4	5
6.	Some ideas are explained better by my peers than by my teacher.	1	2	3	4	5
7.	Some group members wind up doing most of the work.	1	2	3	4	5
8.	I learn best when I work independently.	1	2	3	4	5

Feeling

9.	I am a valuable member of my group.	1	2	3	4	5
10.	Other group members have interesting information to offer.	1	2	3	4	5
11.	I prefer to compete rather than cooperate.	1	2	3	4	5
12.	Other group members want me to be successful.	1	2	3	4	5
13.	It is upsetting when others don't agree with me.	1	2	3	4	5
14.	Working cooperatively puts too much pressure on me and the other group members.	1	2	3	4	5

Acting

15.	We should work in cooperative groups more often.	1	2	3	4	5
16.	Working cooperatively helps prepare me for working with others.	1	2	3	4	5

APPENDIX J
CONCEPT MAPPING EVALUATION PROCEDURES

Rationale: Scoring began with 85 points being awarded for each completed concept map, and positive and negative points were added to or subtracted from this base. No completed concept maps could receive a score below 70 or above 100 regardless of the number of positive or negative points received. It was the opinion of the support group that a completed map should not receive a failing grade and that a score of 100 was adequate for determining mapping excellence.

Scoring Checklist:

1. Number of Concepts
The minimum number of concepts was 25. One point was added for every additional five concepts properly positioned and used.

2. Overall Neatness
Overall map neatness was expected. As many as three points could be deducted from map scores depending upon the degree of disorder.

3. Hierarchical Reading Flow
Evaluators should have been able to "read" through concepts maps from top to bottom following logical reasoning. As many as three points could be deducted if the map did not read easily.

4. Connecting Lines
All concepts should have been connected by lines with one or two other concepts. One point was deducted for each unconnected concept.

5. Labelled Lines
All linking lines should have been labelled with connecting terms. One point was deducted for each unlabelled proposition.

6. Conceptual Ordering
While many hierarchical alternatives were possible, incorrect placements received negative points. One point was deducted in the case of a simple reversal of two concepts, two points were deducted if concepts were misplaced by more than one position, and three points were taken away for glaring faults with map order.

7. Misconceptions or Errors
Up to three points were deducted from map scores depending upon the degree of inaccuracy.

8. Direct Relationships
One point was deducted if a concept was not linked to another, directly related concept (e.g., color blindness should have been linked to sex-linked traits).

9. Branching
Up to three extra points were added for further degrees of differentiation above what was expected.

10. Propositional Terms
Up to three extra points were added for strong, descriptive propositional linkages.

11. Cross-links
Students were encouraged to look for cross-links in the closing stages of concept map construction. Two or three extra points were awarded for each valid cross-link.

12. Creative Use of Knowledge
Up to three additional points were awarded for conceptual placements illustrating novel interrelationships.

APPENDIX K

EVALUATION CHART FOR TRANSFER PROBLEM SOLVING VIDEO MEASURE ON ANIMAL BEHAVIOR (PRIMARY ANSWERS ARE DESIGNATED BY ** AND SECONDARY ANSWERS BY +)

NEADING	SPIDER	INSECT FLIGHT	MANTIS	ANTS	ARMY ANTS	FROG JUMPING	FROG CROAKING	SNAKES CURLING	BIRD DANCE	WNALES	LIONS	LEMUR	GORILLA	NAND WRITING
BEHAVIOR	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
REFLEX				◆	◆	◆					◆	◆		
CONDITIONING													••	
REASONING													◆	◆
SIGHT			◆		◆	◆			◆		◆	◆	◆	◆
TASTE				◆	••						◆	◆	◆	
STIMULUS					◆	◆	◆	◆	◆	◆	◆	◆	◆	
TRIAL AND ERROR						◆						◆	◆	◆
TERRITORIALITY	◆	◆			◆		◆		••	◆		◆		
INSTINCT	••	••	••	◆	••	••	◆	◆	◆	◆	◆	••	◆	
PHEROMONE				••	◆			••				••		
TOUCN			◆		◆	◆					◆	◆	◆	◆
SMELL					◆			◆			◆	◆	◆	
RESPONSE		◆		◆	◆	◆			◆	◆	◆	◆	◆	
INBORN BEHAVIOR	••	••	••	◆	••	••	◆	◆	◆	◆	◆	••	◆	
ACQUIRED BEHAVIOR											◆	◆	◆	••
SOCIAL BEHAVIOR				••	••		◆	◆	◆	◆	••	◆	••	◆
SENSES				◆	◆	◆			◆	◆	••	◆	◆	
NEARING							◆			◆	◆	◆		
COURTSNIP		◆					••	••	••	◆			◆	

APPENDIX L
ANOVA DATA

ANOVA to Examine Pretest Group Differences for Genetics

Genetics Content Pretest

Source	df	SS	F	Pr>F
Sex	1	1.00457	0.06	0.8031
Trt	2	15.8279	0.47	0.6245
Sex*Trt	2	39.4360	1.18	0.3138

ANOVAs to Examine Pretest Group Differences for Animal Behavior

Behavior Content Pretest

Source	df	SS	F	Pr>F
Sex	2	38.0946	0.16	0.8536
Trt	1	136.2944	1.14	0.2909
Sex*Trt	2	284.7607	1.19	0.3125

Commercial Transfer Problem Solving Pretest

Source	df	SS	F	Pr>F
Sex	2	3.2014	0.27	0.7652
Trt	1	19.5290	3.28	0.0752
Sex*Trt	2	9.7908	0.82	0.4445

Researcher-Constructed Transfer Problem Solving Pretest

Source	df	SS	F	Pr>F
Sex	2	47.5094	0.99	0.3788
Trt	1	48.2436	2.00	0.1621
Sex*Trt	2	58.8276	1.22	0.3019

ANOVA to Examine Pretest Group Differences for Solids, Liquids, and Gases

Solids, Liquids, and Gases Content Pretest

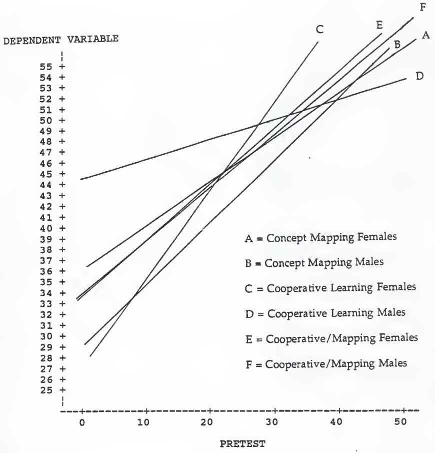
Source	df	SS	F	Pr>F
Sex	2	6.6558	0.57	0.5694
Trt	1	5.2110	0.89	0.3493
Sex*Trt	2	7.6564	0.65	0.5237

ANOVA to Examine Pretest Group Differences for Atomic Structures

Atomic Structure Content Pretest

Source	df	SS	F	Pr>F
Sex	2	30.1304	1.85	0.1671
Trt	1	29.7602	3.65	0.0611
Sex*Trt	2	17.1908	1.09	0.3430

APPENDIX M
PRETEST x TREATMENT x GENDER INTERACTION FOR ANIMAL BEHAVIOR LOW-LEVEL POSTTEST



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BIOGRAPHICAL SKETCH

Henry Ronald Penello lived the first 18 years of his life in Rochester, New York. During these early years, Henry spent most of his time playing baseball or working to achieve an Eagle Scout Award. After graduating from Plattsburgh State University College with a Bachelor of Arts degree in biology, Henry attended the University of Rochester where he worked part-time to achieve his Master of Arts degree in science education.

After teaching 7th and 8th grade science and math in a private school for one year, Henry took a job teaching 7th grade life science in Webster, New York where he stayed for 11 years. For a variety of reasons, Henry and his wife Marianne decided to interview for teaching positions overseas and received a job working for the American School of The Hague in the Netherlands. Their first appointment was a unique teaching experience in a small one-room schoolhouse where Henry and Marianne were the only teachers for 11 students aged seven through eleven. After this short-term appointment, Henry and Marianne moved onto the larger campus of the American School of The Hague where Henry became the 7th grade science teacher and team leader and Marianne took a job teaching 3rd grade.

After seven years overseas, and a beautiful new addition by the name of Jennifer, Henry decided that he would like to pursue a doctoral degree in science education from the University of Florida. At the same time, the publishers of Harcourt, Brace, and Jovanovich asked Henry to write some of the activities for their new 7th grade life science text.

Now that Henry has finished his doctoral program, he will be applying for a position as a faculty member with a university where he can work with faculty, science teachers, and science-teachers-to-be in an effort to extend the research begun in this study.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

M. B. Rowe, Chair
Professor of Instruction and Curriculum

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Linda Cronin-Jones

Linda Cronin-Jones, Cochair
Assistant Professor of Instruction and Curriculum

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Pat Ashton
Professor of Foundations of Education

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

E. J. Bolduc
Professor of Instruction and Curriculum

This dissertation was submitted to the Graduate Faculty of the College of Education and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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